Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://archive.org/details/proceedingsofindv96indi

PROCEEDINGS

of the

Indiana Academy of Science

Founded December 29, 1885

•

Volume 96
1986

•

DONALD R. WINSLOW, Editor
Indiana University
Bloomington, Indiana

•

Spring Meeting
April 25, 26, 1986
Spring Mill State Park
Mitchell, Indiana

•

Fall Meeting
November 13, 14, 15, 1986
University of Indianapolis
Indianapolis, Indiana

Published at Indianapolis, Indiana
1987

1. The permanent address of the Academy is the Indiana Academy of Science, 140 North Senate Avenue, Indianapolis, Indiana 46204.

2. **Instructions for Contributors** appear at the end of this volume.

3. **Exchanges.** Items sent in exchange for the *Proceedings* and correspondence concerning exchange arrangements should be addressed:

John Shepard Wright Memorial Library of the Indiana
Academy of Science
140 North Senate Avenue
Indianapolis, Indiana 46204

4. *Proceedings* may be purchased through the Library at $12.00 for each volume.

5. **Reprints of technical papers** often can be secured from the authors. They cannot be supplied by the library nor by the officers of the Academy.

6. The Constitution and By-Laws reprinted from Vol. 95 are available to members upon application to the Secretary. Necrologies reprinted from the various volumes can be supplied to relatives and friends of deceased members by the Secretary.

7. Officers whose names and addresses are not known to correspondents may be addressed in care of the library.

The *Proceedings* is abstracted and/or indexed, among others, in the following publications:

Agricola
Agris
Agrindex
Biological Abstracts
BIOSIS Previews
C.A.B. Abstract Journals
Cambridge Scientific Abstracts
CASSI
Chemical Abstracts
Cumulative Book Index
GEOREF
Index to Scientific and Technical Proceedings

Editorial Board
1986-87

Donald R. Winslow, Chair
Office of School Programs
Indiana University
Bloomington, IN 47405

Hans O. Andersen
Dept. of Science and Environmental
Education
Indiana University
Bloomington, IN 47405

Rita Barr
Dept. of Biological Sciences
Purdue University
West Lafayette, IN 47907

Ernest E. Campaigne
Dept. of Chemistry
Indiana University
Bloomington, IN 47405

William R. Clark
Dept. of Psychological Science
Ball State University
Muncie, IN 47306

Robert F. Dale
Dept. of Agronomy
Purdue University
West Lafayette, IN 47907

James R. Gammon
Dept. of Zoology
DePauw University
Greencastle, IN 46135

James H. Kellar
Dept. of Archaeology
Indiana University
Bloomington, IN 47405

Benjamin Moulton
Dept. of Geography-Geology
Indiana State University
Terre Haute, IN 47809

Van E. Neie
Dept. of Physics
Purdue University
West Lafayette, IN 47907

John F. Pelton
Rt. 2, Box 404
Nashville, IN 47448

Alfred Schmidt
Dept. of Mathematics
Rose-Hulman Institute
Terre Haute, IN 47803

J. Dan Webster
P.O. Box 292
Hanover, IN 47243

John O. Whitaker, Jr.
Dept. of Life Sciences
Indiana State University
Terre Haute, IN 47809

Bernard S. Wostmann
Lobund Laboratory
University of Notre Dame
Notre Dame, IN 46556

Frank N. Young
Dept. of Biology
Indiana University
Bloomington, IN 47405

TABLE OF CONTENTS

Page

Officers and Committees for 1986 3

Minutes of the Spring Meeting (Executive Committee) 11

Minutes of the Spring Meeting (Council) 12

Minutes of the Fall Meeting (Executive Committee) 17

Minutes of the Fall Meeting (Council) 18

Minutes of the Fall Meeting (General Meeting) 24

Minutes of the Budget Committee Meeting 29

Annual Financial Report 33

Annual Report, Youth Activities 38
    Hoosier Science and Engineering Fair 41
    Indiana Science Talent Search 41

Necrology, Fay Kenoyer Daily, Necrologist 44

Corporate Members of the Academy 50

New Members for 1986 51

ADDRESSES AND CONTRIBUTED PAPERS

Presidential Address
    "Quo Vadis or If Nobody Does Anything, Nothing Will Be Done," Ernest E. Campaigne 57

"Speaker of the Year" Address, 1986-87
    "Science and National Security," Ruth H. Howes 61

Anthropology

C. Michael Anslinger—Archaeological Excavations at the Lattas Creek Site (12-Gr-29), Greene County, Indiana* 71

Ruth A. Brinker—Progress in the Treatment of Cultural Resources in the Coal Fields of Indiana* 71

Mark E. Cantin—Preliminary Report of Test Excavation of Swan's Landing Site (12Hr 304), Harrison County, Indiana, 1986* 71

Donald R. Cochran—Ceramics and Ceramic Sites in the Upper Wabash Drainage: A Regional Problem 72

James W. Kendrick and Robert E. Pace—A Comparison of Site Frequencies and Natural Settings in the Tennyson and Shoals Survey Areas in Southwestern Indiana* 72

Brian G. Redmond—The Yankeetown Phase: An Emergent Mississippian Cultural Manifestation in the Lower Ohio River Valley* 72

Kenneth B. Tankersley—Significant Clovis Sites in Southwestern Indiana* 72

Curtis H. Tomack—Archaeological Research in the Coal Mining Area of Southwestern Indiana* 72

---

*Abstracts

Page

MARY E. WAITE, HOLLY A. WAGNER AND ROBERT E. PACE—Archaeological Investigation of the DeWeese-Preston House* 73

FRANK N. BURKETT AND RONALD HICKS—Site Distribution and Physiographic Zones along the Big Blue River Glacial Sluiceway 75

SHERRI L. HILGEMAN AND MARK R. SCHURR—The 1986 IU/GBL Excavations of the Stephan-Steinkamp Site (12Po33) 83

MARK R. SCHURR—A "Partial Cremation" from the Angel Site, Vanderburgh County, Indiana 91

Botany

PRADEEP K. BHATTACHARYA—Changes in Host-nuclear Macromolecules in Resistant and Susceptible Barley to Infection by *Erysiphe graminis* f. sp. *hordei* Culture CR3* 95

K. MICHAEL FOOS AND JUDITH A. ROYER—Optimum Growth Temperature for *Pilobolus** 95

R.J. GREEN, JR. AND G.L. WILEY—*Verticillium dahliae* as a Biocontrol Agent of Velvetleaf *Abutilon theophrasti** 95

ALAM KHAN AND C.M. WEAVER—Efficiency and Pattern of ^{65}Zn Incorporation into Soybean Seeds by Root Absorption, Stem Injection, and Foliar Application* 96

RICHARD X. LATIN—Incidence and Control of Cucurbit Powdery Mildew in Indiana* 96

THOMAS E. MAXAM AND KATHRYN J. WILSON—Ultrastructure of Articulated Laticifers in *Stapelia bella* (Asclepiadacea)* 96

PEGGY L. RUCKMAN AND RICHARD L. WHITMAN—Aquatic Plant Distribution and Mapping of Selected Ponds of Miller Woods, Indiana Dunes National Lakeshore* 96

WILLIAM STILLWELL, DANIEL BELCHER AND STEPHEN WASSALL—Comparative Effects of Abscisic Acid and Indole Acetic Acid on Phospholipid Bilayers* 97

KATHRYN J. WILSON AND KERRY B. DUNBAR—Histochemical Observations of Embryogenesis in Suspension Cultures of *Asclepias tuberosa* (Asclepiadaceae)* 97

GARY E. DOLPH—The Variation of Four Bioclimatic Indexes in Indiana 99

JERRY J. NISBET AND MARILYN SUE VESELACK—Cell and Tissue Development in One and Two Year Old Culms of *Arundo donax L.* 113

GAIL E. RUHL, DONALD H. SCOTT, RICHARD X. LATIN AND PAUL C. PECKNOLD—A Compilation of Plant Diseases and Disorders in Indiana - 1986 115

MICHAEL SIMINI, RICHARD G. SNYDER AND JAMES E. SIMON—Differential Sensitivity of Muskmelon and Watermelon Cultivars to Ozone-induced Foliar Injury 121

Cell Biology

MARK ALBRECHT, WILLIAM STILLWELL AND STEPHEN R. WASSALL—Effects of Retinoids on Phospholipid Bilayers* 129

---

*Abstracts

Page
SHIRLEY A. BAYER—Development of the Neostriatum in the Rat Brain* 129

ANGELA M. BURKE AND PANG FAI MA—A Comparative Study of the Hamster Kidney Cell Line BHK-21 (C-13) and Normal Hamster Kidney Tissues* 129

E.A.G. CHERNOFF—Adhesion and Expansion of Epithelial Cell Sheets* 130

THOMAS A. COLE, WILLIS H. JOHNSON AND RUCHIR SEHRA—Identification of Members of Species-groups of Genus *Paramecium* with Fluorescent, DNA-binding Dyes* 130

DAVID M. GIBSON, STEVEN J. MILLER AND TED GOODSON, III—Degradation of Liver HMGCoA Reductase in Vitro* 130

A. GUBITOSI AND R.J. STARK—Effects of Extracellular Sodium and Calcium on Acetylcholine Induced Hyperpolarizations in Mouse Parotid Cells* 131

MICHAEL I. LEE, SCOTT A. SMITH AND ALICE S. BENNETT—Influence of Dietary Fatty Acids on Murine Mammary Cell Types* 131

MICHAEL S. MALONEY AND JEANNETTE L. DANIEL—Con A Binding Sites in the Ciliate *Stentor coeruleus* Are Located in the Membranellar and Somatic Cilia* 131

JOHN W. MUNFORD AND JOSEPH E. TRUMPEY—Diabetes-induced Decrease in Sodium Pump Activity in Rat Soleus Muscle* 132

BRUCE PICKELHEIMER AND RICHARD S. MANALIS—Effect of Caffeine on Contractility of Frog Skeletal Muscle* 132

DANNY LEE ROBERSON AND RICHARD S. MANALIS—Neurotransmitter Release Simulation* 132

PATRICIA R. WALSH AND MICHAEL S. MALONEY—Calmodulin Antagonists Inhibit Oral Regeneration in the Ciliate *Stentor coeruleus** 132

STEPHEN P. ZIMMER AND JOAN E. LAFUZE—Serum Angiotensin Converting Enzyme Changes in Rabbits Following Neutrophil Activation *in vivo**... 133

TORSTEN ALVAGER AND THOMAS KING—Energy Expenditure and Maximum Life Span 135

RITA BARR, OWEN MARTIN, JR. AND FREDERICK L. CRANE—Redox-induced Proton Excretion by Cultured Carrot Cells Is Affected by Protonophores and Inhibitors of ATPase 139

CHARLES L. SCHAUF AND FLOYD A. DAVIS—Symptomatic Therapy for Demyelinating Diseases: The Role of Basic Science 145

Chemistry

JOHN BAIN, VIDA FARAZI AND BRUCE N. STORHOFF—Functionalized Crown Ethers: Benzo Crowns with P(III) Centers* 159

MOHAMMAD BEHFOROUZ, HAMIDEH ZARRINMAYEH AND MARK A. HORN—Studies Toward the Total Synthesis of Lavendamycin Methyl Ester, an Antitumor Antibiotic Agent* 159

KENNETH L. BUSCH—Applications of Chromotography/Secondary Ion Mass Spectrometry* 159

---

*Abstracts

Page

CHERYL A. BYE AND JAMES P. RYBARCZYK—Atomic Spectroscopic and Neutron Activation Analyses of Trace Heavy Metals in Water Supplies Surrounding a Municipal Landfill* 160

S.W. DHAWALE—Interaction of Some Metals and Tetrathionate Ions* 160

VIDA FARAZI, M. BRIAN ARNOLD AND BRUCE N. STORHOFF—The Preparation of Functionalized Aza Crown Ethers* 160

SUSAN J. GANION, PAUL L. BOCK AND LYNN R. SOUSA—Potassium Ion Induced Enhancement of Crown Fluorescence by Displacement of a Complexed Quencher* 160

MARY E. HUSS, JEROME I. KAPLAN, STEPHEN R. WASSALL AND WILLIAM STILLWELL—Electron Spin Resonance of Membranes* 161

RICHARD A. KJONAAS AND DOUGLAS SANQUENETTI—Reactions of Lithium Triorganozincates with Acid Halides* 161

TERRY L. KRUGER, TIMOTHY T. CURRAN AND MOHAMMAD BEHFOROUZ—Electron Impact Mass Spectrometry of β-Alkylhydrocinnamate Methyl Esters* 161

DAVID L. MCCOLLUM AND PAUL L. BOCK—Validation of a Test to Identify Erythro and Threo Diastereomers of RCHDCHDX Compounds: Variable-temperature NMR Studies of 2-Chloroethanol* 161

PANG FAI MA AND JEFFREY T. STARKEY—A Study of Adenosine Deaminase and Its Conversion Factor in Normal and Pathological Human Serum* 162

THOMAS E. MABRY, C. DAVID WHITESELL AND LYNN R. SOUSA—A Search for a Flashier Crown: Synthesis of a Crown Ether with Potassium Ion Enhanced Fluorescence* 162

JOHN SHARKITT, GREGORY A. STEPHENSON AND JAMES P. RYBARCZYK—Three-dimensional Profiling of Matrix-interferences in the ICP* 162

KAY STEPHENS, SUZY POPE, ERIC R. JOHNSON AND TERRY L. KRUGER—The Use of Pyridine to Quench the Dansylation of Amino Acids* 163

KIMBERLY K. STROUSE AND ABBAS PEZESHK—Magnetic Resonance Investigation of Metal Complexes of Antidiabetic Drugs* 163

STEPHEN C. SWINNEY AND ABBAS PEZESHK—Spectroscopic Studies of Spin-labeled Tetracycline Metal Complexes* 163

ATILLA TUNCAY AND ROBERT M. MORIARTY—Reactions of Phenyl (β-N-benzenesulfonyl indolyl) Iodonium Chloride with Soft Anions* 163

WILLIAM E. WHITE AND EUGENE S. WAGNER—The Mechanism of L-Ascorbic Acid Entrapment in Human Erythrocytes* 164

E. CAMPAIGNE AND DAVID TEMPLER—Michael Addition and Derivatives of 2-Carboxamido-3-phenylindenone 165

E. CAMPAIGNE AND DAVID TEMPLER—Substituted Derivatives of 3a,4,5,6—Tetrahydrosuccinimido[3,4-b]acenaphthen-10-one.II 173

MARIE HANKINS—Who's Teaching Chemistry in Indiana High Schools? 181

J.L. KIRSCH AND L.J. LUCCHESE—Solution Calorimetry Studies of Hydrogen Bonding in Aliphatic Alcohols 185

---

*Abstracts

Page

J.L. KIRSCH AND B.F. VOLKMAN—An Ab Initio Molecular Calculation on Aromatic-tetracyanoethylene Charge Transfer Complexes 189

JOSEPH R. SIEFKER AND LESTER A. PAGE, JR.—A Study of the Coordination Compounds of Some Transition Metals with 2-amino-2-methyl-1,3-propanediol 197

Ecology

CHARLES L. BAUBE—Mechanisms of Reproductive Isolation in Two Sympatric Stickleback Species* 199

JAMES W. BERRY—Notes on the Life History of the Intertidal Spider *Paratheuma insulana* (Araneae; Desidae)* 199

SPENCER A. CORTWRIGHT—Bimodal Size Distributions of Even-aged Populations: Their Origins and Effects on Community Structure in Larval Salamanders* 199

L.D. FARLEE AND B.C. FISCHER—Early Root Development of Planted Red Oak Seedlings in Clearcut Forest Openings* 200

ANGEL V. GOCHEE AND RICHARD L. WHITMAN—Aquatic Invertebrates and Phytoplankton of Miller Woods Ponds, Indiana Dunes National Lakeshore* 200

MARION T. JACKSON AND D. BRIAN ABRELL—Two Decades of Change in the Forest Structure of Virgin Coast Redwoods (*Sequoia sempervirens*) D. Don (Endl.) in Stout Grove, Del Norte County, California* 200

JANE F. KOSKA—Evolution of Reproductive Isolation in Two Species of Toad* 200

MARK S. McCLAIN—Ginn Woods: An Undisturbed Virgin Forest in East-central Indiana* 201

THOMAS S. McCOMISH—Microcosm Acid Rain Experiments with Water from Oriole Pond, Perry County, Indiana* 201

CRAIG E. NELSON, SCOTT J. BARTON AND DAVID F. PARKHURST—More on: Do Tadpoles Die for Their Siblings?* 201

GUSTAVO A. ROMERO—Pollination, Nutrient and Energy-limited Female Reproductive Success in *Catasetum ochraceum* Lindl. (Orchidaceae)* ... 202

PAUL E. ROTHROCK—Aspects of the Biology of *Carex woodii* Dew. (Cyperaceae)* 202

W.J. ROWLAND—Aggression versus Courtship in Sticklebacks: The Role of Habituation* 202

WILLIAM J. SHEPHERD AND STEPHEN A. PERRILL—Analysis of Playback-record Responses in the Male Cricket Frog, *Acris crepitans** 202

PAUL T. SHERWOOD AND GEORGE R. PARKER—Disturbance Effects in Oak Dominated Forests of Central Indiana* 203

EDWIN R. SQUIERS AND LEONARD H. ROBBINS—The Relationship between Weed Community Development and Tillage Type in Grant County, Indiana* 203

ROD WALTON—The Assessment of Interactions among Ovipositing Goldenrod Gall Flies, *Eurosta solidaginis*, Fitch* 203

---

*Abstracts

Page

JEFFREY S. WARD AND GEORGE R. PARKER—Gap Structure in a Mature Till Plain Forest* 204

JOHN A. BACONE AND THOMAS W. POST—Effects of Prescribed Burning on Woody and Herbaceous Vegetation in Black Oak Sand Savannas at Hoosier Prairie Nature Preserve, Lake County, Indiana 205

JAMES D. BARTON AND DAMIAN V. SCHMELZ—Thirty Years of Growth Records in Donaldson's Woods 209

JOHN S. CASTRALE—Pesticide Use in No-till Row-crop Fields Relative to Wildlife 215

JOHN CASTRALE, STEVE E. BACKS AND DAVID HOWELL—Avian Surveys along Two River Segments in Southern Indiana 223

B.C. FISCHER, J.A. KERSHAW, JR., D.W. GEORGE, C.A. GEORGE AND W.L. MILLS—Tree Regeneration Response to Clearcutting on the USFS Brownstown Ranger District 231

DAVID HOWELL, DONALD E. BUCKLAND AND ROY GRIMES—Indiana's Property Tax Incentive Program for Wildlife Habitat Protection 243

ROBERT E. ROLLEY AND JIMMY F. NEW—Abundance and Characteristics of Northern Indiana Wetlands 249

JOHN RICHARD SCHROCK AND JACK R. MUNSEE—A Comparison of Surface Vegetation on Unreclaimed 1949 Indiana Coal Spoilbanks in 1964 and 1981 257

KIMBERLY A. WADE AND ERIC S. MENGES—Effects of Fire on Invasion and Community Structure of a Southern Indiana Cedar Barrens 273

Engineering

DAVID D. CHESAK—Fault Tolerant Computing* 287

DONALD T. CHESAK AND DAVID D. CHESAK—Engineering Aspects of Heavy Duty, On and Off Highway, Trailers* 287

BRUCE MUELLER, BRUCE A. BLACK AND DAVID R. VOLTMER—PC-SIG: A Communications Systems Laboratory* 287

JOHN M. ULRICH—The NASA Technology Utilization Program* 287

Entomology

GENE KRITSKY—Insects in Traditional Chinese Medicine* 289

ROBERT W. MEYER—Insects and Other Arthropods of Economic Importance in Indiana in 1986 291

MARK H. SHOUR AND DONALD L. SCHUDER—Host Range and Geographic Distribution of *Chionaspis heterophyllae* Cooley and *C. pinifoliae* (Fitch) (Homoptera: Diaspididae) 297

---

*Abstracts

Page

Environmental Quality

GREG R. BRIGHT—Background Levels of Potential Toxicants in Indiana Stream and Lake Sediments* 305

PETER A. HIPPENSTEEL—The Water Quality of Northeastern Indiana Lake Inflows* 305

RUSSELL HOLLAND AND DEBORAH D. ROSS—Enhancement of Phenol Biodegradation by Soil Inoculation* 305

ROBERT A. PRIBUSH, PATRICIA S. MUIR, BRADLEY H. CARTER, MICHAEL J. STEVENSON AND KIMBERLY A. WADE—Creation of an Urban Acid Deposition Database* 306

ROBERT A. PRIBUSH AND MICHAEL J. STEVENSON—A Computer Raindrop Model Used to Predict the Equilibrium of pH of Rainfall over Indianapolis* ... 306

DEBORAH D. ROSS—Impact of Heavy Metal Pollution on Sediment Bacteria in the Maumee River* 306

JEROME RUD, HAROLD BONHOMME, GREG BRIGHT, NEIL PARKE AND JAMES STAHL—Results of Surface Water Investigations of the Grand Calumet River/Indiana Harbor Canal Basin* 306

J.E. SIMON, M. SIMINI, R. GRANT, B. MCFEE AND D. REINERT—Air Quality Monitoring in Southwest Indiana During the 1986 Growing Season* 307

C. LEE BRIDGES, H.L. BONHOMME, G.R. BRIGHT, D.E. CLARK, J.K. RAY, J.L. RUD, J.L. WINTERS AND T.E. LAUER—Summer Primary Productivity and Associated Data for Four Indiana Rivers 309

Geology and Geography

RICHARD F. DUWELIUS—Ground-water Modeling of Small Watersheds in the Coal-mining Region of Southwestern Indiana* 315

W.S. GADDIS AND N.R. SHAFFER—Sulfur Isotope Ratios in Indiana Sulfide Minerals* 315

WILLIAM A. GUSTIN—Examination of a Popular Belief: Is There a Relationship Between Winter and Summer Temperatures?* 316

WALTER A. HASENMUELLER, LOUIS V. MILLER AND JIMMY J. JOHNSON—An Estimate of Indiana's Coal Reserves that Comply with Current Sulfur Dioxide Emission Standards* 316

ROGER F. BONEHAM AND THOMAS E. KESLER—New Reef Structures in Daviess County, Indiana 317

GARRE A. CONNER—*Neuropteris* Ovata in Lacustrine Facies Sequence below Raben Branch Member (Patoka Fm.) at St. Wendel, Indiana and Related Carboniferous Reconnoissance Investigations 321

PAUL K. DOSS, DAVID E. GROW AND ROBERT D. HALL—Stream-variable Response to a Change in Surficial Geology: Middle Fork, Big Walnut Creek, Hendricks County, Indiana 333

---

*Abstracts

Page

HENRY H. GRAY—Spotting Spurious Stream Names on Topographic Maps of Indiana 345

History of Science

DONALD J. COOK—Chemistry at Indiana Asbury-DePauw in the Nineteenth Century* 351

N. GARY LANE—The Richard Owen Geological Survey of Indiana 1859-1860 353

FRANK N. YOUNG—Fernandus Payne, Educator and Scientist 361

Microbiology and Molecular Biology

SHEILA M. BAILEY AND CARL E. WARNES—Separation and Characterization of Chitinase and Chitobiase from CDC Group *EF4a** 367

M. BARD, A.S. BURNETT, L.S. BURROWS AND R.A. PARKER—Isolation of Mevinolin Resistant Strains in Yeast* 367

NANCY C. BEHFOROUZ AND CHARLOTTE WENGER—Decreased Survival of *Leishmania tropica* in Macrophages Treated with Cyclosporine A* 367

JAY G. CALVERT AND EDWARD H. SIMON—Bathocuproine Disulfonate and Interferon: Progress and Prospects* 368

FREDERICK FAUST AND HARRY W. JARRETT—Location of Sites on Calmodulin that React with a Phenothiazine* 368

ROBERT GARCIA—S-Adenosylmethionine Synthetase and Spore Germination in *Mucor racemosus** 368

EDWIN M. GOEBEL, JENNY I. JOCKEL AND JAMES K. MATCHUNY—Isolation and Identification of *Azospirillum* and *Herbaspirillum* Strains from Soil of Several Eastern States* 368

EDWIN M. GOEBEL, JAMES J. TOBOLSKI AND DENNIS A. FRIEDLE—The Effect of *Azospirillum* and *Herbaspirillum* Inoculation upon the Yield of Winter Wheat (Triticum aestivum)* 369

STANLEY N. GROVE, RICHARD F. IANNACONE, CARMELO A. MILANO AND MARY J. CLANCY—Characterization of SPR6, a Sporulation Regulated Gene in Yeast* 369

KATHLEEN HARDY, CAROL BRANKA, ELIZABETH WATSON AND KARA EBERLY—Dietary Effects of Tannic Acid on the Gut Microflora of Sprague-Dawley Rats* 369

LARRY R. MASSOM AND HARRY W. JARRETT—Synthesis and Characterization of Protein A-silica for High Performance Affinity Chromatography* 370

MARTHA M. RITTER AND ROBERT PINGER—Lyme Disease in Indiana: Isolation of *Borrelia burgdorferi* from Ticks (*Dermacentor variabilis* and *Amblyomma americanum*) and White-footed Mice* 370

CAROLYN N. VANN, LAUREN A. PLAYL AND LOUIS A. SHERMAN—The Construction of Three Hybrid Cloning Vectors and the Use of Low Iron Medium to Improve Transformation Efficiency in the Cyanobacteria *Anacystis nidulans* R2 and *A. nidulans* R2 SPc. 370

---

*Abstracts

Page

RICHARD M. KLINE AND CHRISTOPHER A. SCHMALZ—The Use of Aniline as an Indicator of Persistence in Environmental Studies 371

I.L. SUN, P. NAVAS, D.J. MORRÉ AND F.L. CRANE—Modification of Pyridine Nucleotide Pools in Hela Cells Grown under Growth Promoting Factors 377

Physics and Astronomy

TORSTEN ALVAGER, ANGEL ANEZ, DAVID BEACH AND CINDY THOMAS—Fiber Optic System for Sensor Applications and Environmental Control* 385

MALCOM E. HULTS AND ROGER L. SCOTT—Observing Halley's Comet from Indiana and Brazil* 385

ELMER N. NUSSBAUM, ROGER W. ROTH AND JON A. ROTH—Radon Daughter Concentrations in Selected Homes in Indiana, Illinois and Michigan* ... 385

GERALD P. THOMAS AND SUE THOMPSON—Voice Recognition and Speech Synthesis as Aids in Real-time, Computer-aided Measurements of High Energy Physics Star Events in Nuclear Emulsion* 386

DIANA S. BENNETT, MATTHEW J. BUCHKOWSKI, CHERYL A. BYE, DAVID L. LOEWENSTEIN AND DAVID R. OBER—Fast-neutron-Activation Analysis of Various Water Sources of East Central Indiana 387

WILLIAM W. WONG, CHERYL A. BYE AND DAVID R. OBER—An Investigation of the April 1986 Chernobyl Radioactivity Releases as Detected in Muncie, Indiana 397

Plant Taxonomy

D. BRIAN ABRELL AND MARION T. JACKSON—Two Decades of Change in the Tree Stratum of Hoot Woods, Owen County, Indiana* 401

JAMES R. ALDRICH AND LEE A. CASEBERE—Leatherleaf Bogs of Indiana* 401

CHARLES HEISER—New Artificial Hybrids in *Helianthus** 401

RICHARD J. JENSEN—Within Tree Leaf Variability and Evidence for a Developmental Difference Between Pin Oak and Black Oak* 402

JOHN W. MCCAIN AND JAMES V. GROTH—Preliminary Polyacrylamide Gel Electrophoresis (PAGE) Survey of Isozymes in Populations of the Bean Rust Fungus* 402

KAY MCCRARY YATSKIEVYCH—Progress toward a Photographic Field Guide to Indiana Wildflowers* 402

FAY KENOYER DAILY—Cryptograms Collected by Thomas G. Lea from Indiana and Ohio, 1836-1842 403

MICHAEL A. HOMOYA—A Floristic Survey of a Limestone Glade in Versailles State Park, Ripley County, Indiana 407

RICHARD H. MAXWELL—Natural Area Remnants within the Indiana Army Ammunition Plant, Charlestown, Indiana: The Little Bluestem Glades 413

---

*Abstracts

Page

REBECCA A. STRAIT, MARION T. JACKSON AND D. BRIAN ABRELL—Comparison of Groundlayer and Shrublayer Communities in Full Canopy and Light Gap Areas of Hoot Woods, Owen County, Indiana 421

GEORGE YATSHIEVYCH, MICHAEL A. HOMOYA AND DONALD R. FARRAR—The Fern Genera *Vittaria* and *Trichomanes* in Indiana 429

GEORGE YATSKIEVYCH AND KAY McCRARY YATSKIEVYCH—A Floristic Survey of the Yellow Birch Ravine Nature Preserve, Crawford County, Indiana ... 435

Psychology

LEAH J. FREELAND AND MICHAEL R. STEVENSON—Changing Attitudes toward Homosexuality* 447

WALTER HARTMANN—A Note on Dangers in Hypnosis* 447

SAMUEL B. SCHNITZER AND ROY W. GEIB—Later Immune Reactivity as a Function of Experience before Weaning and Strain of Mouse: A Preliminary Investigation* 447

KATHRYN N. BLACK, CATHERINE M. ROE AND JULIE A. KABLE—Self-ratings of Masculinity and Femininity by High School Students 449

MARTIN B. WOLSKE, ELIZA HUI CHIEN LIAN AND CURTIS K. LEECH—Kindling Rates in Sprague Dawley Rats as a Function of Copper and Nichrome Electrodes 453

Science Education

CLAUDE D. BAKER—Friends with Fins: Using Fish as an Educational Tool* 459

CARL CHRISTENSON, JACQUELINE CHRISTENSON AND CLAUDE D. BAKER—Experiential Training: Evaluation and Grading of Extended Field Trip Courses* 459

KARL K. KING AND ROSALIE J. KRAMER—Project Map: An Evaluation of a Community* 459

JOHN T. SNOW, DAVID R. SMITH AND SHAWN B. HARLEY—The Purdue Atmospheric Science Education Program for Junior High Science Teachers* 459

PATRICIA DODSON AND RUTH H. HOWES—First Activities of the Physics Kind: Physical Science Activities for the Primary Grades 461

A.J.C.L. HOGARTH—Weight Titrations: A Forgotten Art? 467

GENE KRITSKY—Darwinism in Modern China 473

MARY ANN MORSE—Nature Study: A Practical Science Course for the Non-science Major 477

Soil and Atmospheric Sciences

RICHARD H. GRANT AND WILLIAM W. McFEE—The Relationship between Cl and SO_4 Particulate Concentrations and Air Masses* 481

C.W. LOVELL AND TIMOTHY CROWL—Construction of Highway Embankments over Amorphous Peats and Mucks* 481

---

*Abstracts

Page

E.M. Ossom, N.O. Isirimah, A.G. Ojanuga and C.L. Rhykerd—Acid Sulfate Soils of the Mangrove Swamps of Rivers State, Nigeria 483

Albert Peterlin, James R. McIntyre, Ken L. Scheeringa and James E. Newman—A Polar Area Index Methodology for Forecasting Hemispheric Surface Temperature Trends 489

G.C. Steinhardt, W.C. Moldenhauer and D.P. Franzmeier—The Effects of Bulk Density on Available Moisture in Selected Surface Mine Soil Materials 497

Zoology

Claude D. Baker—A Pigmented Northern Blindfish, *Amblyopsis spelaea*, and Notes on Pigmentation in Amblyopsid Cavefishes* 503

Amy K. Berndtson and Frederick W. Goetz—Proteolytic Enzymes in Brook Trout and Goldfish Follicles during Final Maturation and Ovulation* ... 503

David L. Brand and Pang F. Ma—A Study of Adenosine Deaminase in the Fruit Fly, *Drosophila melanogaster** 503

Priscilla Costello—Studies of Ecology, Ectoparasites, and Other Associates of the Eastern Box Turtle, *Terrapene carolina** 504

David L. Daniell—Histopathology of Experimental *Dendritobilharzia pulverulenta* Infections in Avian Hosts* 504

Grayson S. Davis—Improved Analysis of Physical Forces and Tissue Rheology in Amphibian Gastrulation*... 504

Larry R. Ganion and Mary E. Mohr—Localization of Acetylcholine Binding Sites in Prepubertal Mouse Ovaries* 504

Frederick W. Goetz, F.P. Binkowski, P.D. Lorsch and S.E. Yeo—Sterilization of Chinook Salmon, *O. tshawytascha*, Fry by 17α-methyltestosterone* 505

Ronald L. Helms—Habitat and Food Interrelationships of Shrews in West Central Vigo County* 505

Mohinder S. Jarial and Margaret W. Egar—Ultrastructural Changes in the Proximal Tubule of the Axolotl* 505

Scott A. Leatherland and Thomas H. Cervone—Winter Fishes in Bayou Creek Drainage*... 506

Charissa M. Urbano and Sidney L. Beck—Coteratogenesis of Caffeine and Acetazolamide in Mice* 506

David M. Agee, William J. Alvey, Kenneth D. Berger, Brad J. Leinenbach and Thomas H. Cervone—Winter Fishes of Stinking Fork 507

Ronald L. Richards—The Quaternary Distribution of the Eastern Woodrat, *Neotoma floridana*, in Indiana 513

Susan J. Schulthesis, Kenneth D. Berger, Rusty K. Yeager, David M. Agee and Thomas H. Cervone—Summer Fishes of Pigeon Creek Drainage .. 523

David M. Sever, Stephanie A. Kramer and Susan Duff—The Relation between Ovum Variability and Larval Growth in *Ambystome tigrinum* (Amphibia: Urodela)... 531

---

*Abstracts

Page

DAVID L. SNYDER, VICTOR RIEMENSCHNEIDER AND VIRGIL W. INMAN—The Upland Sandpiper, *Bartramia longicauda*, Breeding Area in South Bend, Indiana 537

JOHN O. WHITAKER, JR. AND WYNN W. CUDMORE—Food and Ectoparasites of Shrews of South Central Indiana with Emphasis on *Sorex fumeus* and *Sorex hoyi* 543

RUSTY K. YEAGER, DAVID S. NICHOLS, SUSAN J. SCHULTHEIS, MICHAEL T. GALBRAITH, SUSAN E. LENN AND THOMAS H. CERVONE—Fishes of Goose Pond and Its Drainage Basin 553

Instructions for Contributors 559

Index 563

Proceedings
of the
Indiana Academy
of Science

INDIANA ACADEMY OF SCIENCE
SPRING MEETING OF THE EXECUTIVE COMMITTEE

April 25, 1986

MINUTES

President Ernest E. Campaigne called the meeting to order at 2:45 p.m. in the Oak Room, Spring Mill Inn, Spring Mill State Park. All members of the Executive Committee were present.

Minutes of the November, 1985, meeting of the Council, the body corresponding to the present Executive Committee under the previous constitution, were approved.

The Secretary reported that a copy of the Resolution regarding science education approved at the 1985 General Meeting had been sent to Dr. H. Dean Evans, State Superintendent of Public Instruction, and that Dr. Evans had expressed his appreciation. In discussion of how the Academy might implement the resolution, it was pointed out that several Academy members serve on the Advisory Council to the Science Education Committee of the Corporation for Science and Technology. They can inform the Science and Society Committee when action seems appropriate. The Indiana Congress for Education is also preparing to enlist public support.

Recommendation will be made to the Council that Kappa Kappa Kappa become an Affiliated Organization.

Appointment of an *ad hoc* committee to make recommendations on school textbooks was approved.

The possibility of a logo for the Academy was discussed. If there seems to be a consensus that one should be designed, Duvall Jones will consider initiating a contest and an appropriate prize.

The need for liability insurance for Academy officers was discussed briefly and will be considered again when more information is available.

Council will be asked to approve an additional $5,000 allocation for research grants.

The President displayed a diagram of the structure of the Academy's organization. If Council approves, it will be published in the *Newsletter*.

Indiana State University invited the Academy to hold its 1987 meetings there. If possible, the Fall meeting will be in late October.

A letter from Ronald Richards of the Indiana State Museum sparked a discussion of how the Academy could help him by suggesting members who could provide advice, programs, etc.

Campaigne introduced amendments to the By-Laws which will be presented to the Council.

The meeting was adjourned at 3:30 p.m.

Respectfully submitted,
Richard L. Conklin, Secretary

INDIANA ACADEMY OF SCIENCE
SPRING MEETING OF THE COUNCIL

April 25, 1986

MINUTES

The meeting was called to order by President Ernest E. Campaigne at 3:35 p.m. in the Oak Room, Spring Mill Inn, Spring Mill State Park. Twenty-seven members were present. Minutes from the Fall 1985 meetings of the Council and the Executive Committee were distributed and approved.

TREASURER'S REPORT

Treasurer Duvall Jones presented a financial report of transactions from January 1 to April 24, 1986. Expenditures are within budgeted limits. 570 members have renewed their memberships for 1986; 600 have not done so as of April 24.

1986 Income to date	$15,110.84
1986 Expenditures	12,419.49
Balance	
Academy Accounts	$17,340.41
Administered Accounts	18,786.78
Total	$36,127.19

Upon motions by Jones, the following modifications in the budget were approved:

Increase Research Grants allocations for 1986 by $5,000

Increase allocation for *Proceedings* by $8,000 to cover anticipated publication costs.

Transfer funds in the operating reserve to Research Grants.

Jones moved that Kappa Kappa Kappa be declared an Affiliated Organization to the Academy in recognition of its long support of the Science Talent Search.

The motion carried.

PRESIDENT'S REPORT

The President distributed a chart depicting the organization of the Academy and recommended that it be published in the *Newsletter*. Alice Bennett suggested that organization of Sections might also be studied.

Campaigne and Donald Winslow are suggesting the publication of a book of abstracts of all the papers to be presented at the Fall meeting. The book would be distributed at the registration table. To facilitate publication, all abstracts must be submitted on a special form which will be distributed with the June *Newsletter*. Additional copies will be available from the Secretary. This year the abstracts will be published in the *Proceedings* as usual; it is possible that a separate volume of *Abstracts* might be published in the future.

The following amendments to the By-Laws of the Academy were circulated to the members in the March *Newsletter*, presented at this meeting by Campaigne, and approved by a vote of those in attendance:

1) Amend By-Laws, Art. VI, Sect. 3, to include a new paragraph (25), as follows:

(25) *Committee on Amendments*. This committee shall consist of three members, with Parliamentarian as Chair. It shall be responsible for all amendments to the Con-

stitution and By-Laws. It shall receive all recommended amendments and review them in terms of their effect on the present Constitution or By-Laws, including conflicting language and impact on Articles and Sections other than those being amended. In case of any such conflict, the Committee on Amendments may revise the language to bring it to agreement with the present Constitution, and, with the consent of the proposer, present it at the next regular meeting of the Council, or it may be returned to the proposer with suggestions for revision. In no case may an amendment to the Constitution or By-Laws be presented for approval by the Council without being first reviewed by the Committee on Amendments. Each proposed amendment must be accompanied by a review statement by the Committee on Amendments.

2) Amend By-Laws, Art. VI, Sect. 3, paragraph (16) *Parliamentarian*, add the sentence: "The Parliamentarian shall serve as Chair of the Committee on Amendments."

3) Amend By-Laws, Art. XII, *Amendments*, to add: Section 2. No amendment, either to the Constitution or By-Laws, may be submitted to the Council for approval unless certified by the Committee on Amendments that the language is not in conflict with other Articles of the Constitution and By-Laws.

REPORTS OF ELECTED COMMITTEES

Academy Foundation Committee

William A. Daily, chair, reported that on March 31, 1986, the Invested Income Account had a total market value of $128,506.79. The market value of the Foundation Account was $47,795.00, and the market value of the John S. Wright Fund was $1,240,118.00.

Research Grants Committee

The Secretary read the report from Austin E. Brooks, chair. Of 30 proposals, 26 were funded at a total cost of $13,964; the average amount awarded was $537. A list of the grants is appended to these minutes.

REPORTS OF STANDING COMMITTEE

Editorial Board

Editor Donald Winslow reported that Volume 94 of the *Proceedings*, the Centennial volume, will be released soon. It will have several added features, including a physiographic map of Indiana and expanded sections reporting the Spring and Fall meetings of 1984. It also contains abstracts or papers representing 225 section presentations.

Emeritus Members Selection Committee

Robert Cooper, chair, recommended that the following members be granted Emeritus status:

Miss Betty VanDerbilt, Nashville, Indiana
Dr. and Mrs. Frank N. Young, Indiana University, Bloomington, Indiana
Dr. Edward J. Compau, Greenfield, Indiana
Dr. Earl C. Smith, Terre Haute, Indiana

The recommendation was approved.

Committee on Fellows

Marvin Carmack, chair, discussed the need for new guidelines, forms, and procedures. The committee will discuss these and present a report at the Fall meeting.

Indiana Science Talent Search

Donald R. Winslow, Director, reported that 51 students participated in the 39th

Annual Science Talent Search. 24 were declared finalists by the committee and were invited to participate in the Honors Program on the weekend of March 7-8, 1986, at the Medical Center Union Building, Indiana University-Purdue University at Indianapolis. $1,000 scholarships were awarded by Kappa Kappa Kappa to Mae-Mae Shieh of West Lafayette (Harrison High School) and Craig Claussen of Kouts High School. George Hudock, Associate Professor of Biology, Indiana University, presented the main address: "Current Applications of Diagnostic Genetic Techniques."

An added dimension of the weekend activities was provided by the Public Service Indiana Symposium, which was designed to invite "new" teachers to the Honors Program and to provide them with ideas for sponsoring students in future talent searches.

Library Committee

Holly Oster, chair, reported that a project begun by Lois Burton is near completion. Its object is to identify and acknowledge services either indexing or abstracting Indiana Academy of Science publications. The information will be made available by the Editor of the *Proceedings.*

Science and Society Committee

Alice Bennett, chair, reported that the committee is considering several matters: 1) A symposium on AIDS for the Fall meeting; 2) Implementation of a Speakers Bureau; 3) A major effort to provide a technical basis for state policy on ground water quality; 4) A group to react to recommend science textbooks; 5) A "master plan" for science education in Indiana.

Youth Activities Committee

Virginia Rhodes, chair, reported on several activities: 1) The committee has been meeting to discuss funding of Academy-supported youth activities; 2) Indiana Science Talent Search was held March 7-8; 3) Twelve regional Science Fairs have been held and 24 students have been named to go to the International Science Fair in Fort Worth, Texas; 4) The Indiana Science Olympiad was held in Michigan City on March 22. Eleven schools participated in the High School division and nine in the Middle School divisions; 5) The first Hoosier Science and Engineering Fair was held at the Children's Museum in Indianapolis on April 17-19, with 70 students participating, six from each Regional Science Fair. It is hoped this will become an annual event.

Dean Christakis, Director of the Junior Academy and the Science Olympiad, submitted a detailed report on their activities. Interested persons may obtain copies from the Secretary.

Representative to the Natural Resources Commission

Damien Schmelz reported that a new nature center will be dedicated at Turkey Run State park. A worsening problem for the Commission pertains to the collapse of bonding companies and the difficulties of coal mine operators needing to obtain new bonds.

Old Business

Benjamin Moulton reported that the *ad hoc* committee to consider appointment of an Executive Secretary has met and will report more fully at the Fall meeting.

The invitation of Indiana State University to act as host for the 1987 meetings was accepted.

The appointment of a Science Education Committee was approved.

The meeting was adjourned at 5:00 p.m.

Respectfully submitted,
Richard L. Conklin, Secretary

INDIANA ACADEMY OF SCIENCE
Spring 1986, Grant Applications Funded

Research Grants Committee Actions

No.	Principal Investigator/ Institution & Dept.	Title	Funded
1.	Len Archer ISU-Life Sciences	Temporal Immunglobulin Responses During Trypanosoma cruzi Infections . . .	$ 500.00
2.	Charles Baube IU-Blmg.-Biology	Mechanisms of Reproductive Isolation in the Genus Gasterosteus	385.00
3.	Mark Binkley ISU—Geography & Geology	Spacial Perspective of Meteorotropisms . . .	700.00
4.	Arvind Chaturvedi Purdue-Geosciences	Application of Landsai Thenatic Mapper Data to Kimberlite Exploration in Brazil . . .	700.00
5.	Spencer Cortwright IU-Blmg.-Biology	Predation and Completion as Factors Determining the Relative Abundance of Aquatic Larvai Amphibian Species	659.00
6.	Douglas Duff IU-So. Bend-Biology	Atrial Natriuretic Factor's Physiological Function . . . in Teleosts	550.00
7.	William Flurkey ISU-Chemistry	Affinity Chromatography of Mushroom Polyphenoloxidase	550.00
8.	Uwe Hansen ISU-Physics	Studies of Vibrating Surfaces Using Holographic Interferometry	600.00
9.	James Hengeveld IU-Blmg.-Biology	Experimental Analysis of Brood Reduction in the Red-winged Blackbird	500.00
10.	Torgeir Johnsen IU-Blmg.-Biology	The Influence of Reproductive Experience and Plasma Testrosterone Level . . . in the Red-winged Blackbird	400.00
11.	Jong Wook Kim ISU-Life Sciences	Analysis of Genomic Double Stranded RNA's from Penicillium stolonifera Virus Complex	500.00
12.	Young-ho Kim ISU-Life Sciences	Construction and Cloning of a Double-stranded cDNA . . .	500.00
13.	Jane Koska IU-Blmg.-Biology	Hybridization Dynamics and Reproductive Isolating Mechanisms in Toads . . .	450.00
14.	Gene Kritsky	Darwinism in China	450.00
15.	Olga Kikal Notre Dame-Biology	Control of Cold Hardiness in Arctic Insects	500.00
16.	Denny McGrath Nature Conserv./Ind. Field Officer	Collection of Rare Plant and Community Baseline Data at Post Oak Barrens Nature Preserve	550.00
17.	Eric Menges Holcomb Res. Institute-Butler	Population Dynamics and Controlling Factors in Silene regia . . . in Indiana	650.00
18.	Marilyn Milberger IU-Blmg.-Biology	Evolution of the Lower Vertebrates	775.00

19.	Paul Sniegowski IU-Blmg.-Biology	Field Experiments on the Role of Experience in Controlling Avian Migration	500.00
20.	David Snyder Lobund Lab-Notre Dame	Study of the Upland Sandpiper Breeding Area in South Bend, Indiana	785.00
21.	Sue Sudar Purdue-Geosciences	Subsurface and Hydrogeologic Investigation Concerning . . . Southside Sanitary Landfill . . . Marion County	500.00
22.	Thomas Waldron ISU-Geography & Geology	Geology & Hydrology of the Cider Fork Karst Valley . . .	500.00
23.	Louise Weber Notre Dame-Biology	Periphyton, Substrates and the Distribution of Grazing Snails	400.00
24.	Licia Wolf IU-Blmg.-Biology	Biparental Care in the Monogamous Dark-eyed Junco . . .	400.00
25.	Theodore Wright IU-Blmg.-Biology	Allozyme Selection in Bufo americanus Tadpoles	400.00
26.	Sewon Yie ISU-Life Sciences	The Study of Replication of Ustilago maydis P-1 Virus . . .	560.00
		Total—	$13,964.00

INDIANA ACADEMY OF SCIENCE
FALL MEETING OF THE EXECUTIVE COMMITTEE

November 13, 1986

MINUTES

President Ernest E. Campaigne called the meeting to order at 1:00 p.m. in the Krafft Conference Room of the Krannert Memorial Library, University of Indianapolis. All members of the Executive Committee were present except the Program Co-chairs.

Minutes of the April 25 meeting of the Executive Committee were approved.

The booklet of *Abstracts* of papers to be presented at Section meetings was distributed by Campaigne. He reported that he had assembled the abstracts in booklet form in approximately twelve hours, and that they had been printed in about two weeks at a cost of approximately $1,150.00, for 750 copies. There was considerable discussion of the future of this publication. A consensus developed to the effect that the *Abstracts* should continue to be printed separately and that the program of the Fall meeting be included in the book, which would be mailed to all members of the Academy well before the meeting. *Abstracts* would then not be published in the *Proceedings*. The opinions of the full membership would be solicited before such a policy would be implemented. The Program Chairs will be asked to distribute a questionnaire at the Friday meeting, and the *Newsletter* will ask for written opinions.

Treasurer Jones presented his report. He is making some changes in his bookkeeping practices, changing from a single - to a double - entry ledger and allocating the management and General Expenses portions of the budget more in keeping with the Internal Revenue Service categories. The question of cost of mailing by Section Chairs to the members of their sections was raised and referred to the Budget Committee. Jones recommended the purchase of a MacIntosh computer for maintaining membership records and preparing mailing labels. The purchase was approved and will be recommended to the Budget Committee. Liability insurance for Academy officers is not available, but Campaigne reported that Indiana University's legal counsel had advised him that such insurance is not necessary. Accident insurance for such events as nature walks might be advisable; the question will be referred to the Budget Committee.

Several amendments to the Constitution will be brought to the Council for their approval. They have been published in the *Newsletter* and will be presented as published except for changing the word "Council" to "Executive Committee" in Article V, Section 3.

Jones reported for the *ad hoc* Logo Committee that eight designs will be displayed at the Registration desk and members will be asked to vote for their choice.

Proceedings

Editor Winslow reported that extensive changes in proof by authors of papers are substantially increasing the cost of publishing the *Proceedings*. A policy for passing these charges on to the authors will be presented to the Council.

Newsletter Editor Schmidt said that more issues per year would be possible and desirable, subject to approval by the Council.

Chair Moulton reported that he has submitted to the Executive Secretary Feasibility Committee a plan for a trial year, but the Committee has not acted. It will meet this evening and consider a recommendation to the Budget Committee.

Marvin Carmack, chair of the Committee on Fellows, presented a proposal to establish an award for 50-year Fellows. He was given permission to address it to the Council.

The meeting adjourned at 3:00 p.m.

Respectfully submited,
Richard L. Conklin, Secretary

INDIANA ACADEMY OF SCIENCE
FALL MEETING OF THE COUNCIL

November 13, 1986

MINUTES

The meeting was called to order by President Ernest Campaigne at 3:10 p.m. in the Krafft Conference Room, Krannert Memorial Library, University of Indianapolis. Twenty-one members were present.

The Treasurer's Report in the minutes of the Spring meeting was corrected by the Secretary, deleting the words "with the exception of research grants," correcting the income to $15,110.84 and the expenditures to $12,419.49, and correcting one sentence to read "Transfer funds in the operating reserve to Research Grants, in order to eliminate a negative balance that has been carried for several years." The minutes were approved as corrected.

TREASURER'S REPORT

Treasurer Duvall Jones distributed his report of transactions from January 1 to November 11, 1986. There are 1,089 members, 128 of whom joined or were reinstated in 1986. 192 who were members in 1985 have not paid 1986 dues; 103 were dropped for nonpayment of 1985 dues.

In summary:

	Academy Accounts	Administered Accounts	Total
1986 Income	$16,747.89	$65,502.99	$82,250.48
1986 Expenditures	12,999.31	61,457.85	74,457.16
Balance: November 11	$18,808.76	$22,420.40	$41,229.16

No adjustments were needed.

Jones recommended that there be no change in the dues structure.

The report was accepted.

REPORTS OF ELECTED COMMITTEES

Academy Foundation

William Daily, chair, reported that as of October 31, 1986, the Foundation Account had a market value of $51,847.02. The John S. Wright Fund had a market value of $1,134,268.90. The Invested Income Account had available to spend assets of $131,105.33.

Research Grants

Austin Brooks, chair, reported that the Fall round of grants brought 12 requests, all of which were funded for a total of $8,582.00. During the summer 12 high school grants were awarded, totaling $1,506.00. Lists of the awards approved are appended to these minutes.

In response to questions, he said that a full report of the work done is required six months after completion. There is no requirement that the work be published, but most recipients present their result at Academy meetings. A request for increased funding will be presented to the Budget Committee. Most of the recipients are graduate students at state universities, in the biological sciences.

REPORTS OF STANDING COMMITTEES

Only those committees whose reports required Council action were heard. Others presented written reports, which are summarized at the end of these minutes.

Nominations

Alice Bennett presented the names of those who will be nominated at the General Meeting.

Fellows

Marvin Carmack presented the names of five members who will be nominated at the General Meeting.

He proposed that special citations be given to people who have been members of the Academy for 50 years, and gold pins to those who have been Fellows for, say, 40 years. After some discussion, the matter was referred back to the committee.

Emeritus

Robert Cooper reviewed the requirements for emeritus membership and presented the names of six people who have recently met these requirements and will be recommended for election at the General Meeting.

Resolutions

William Davies presented two resolutions, one expressing support of the Nature Conservancy and the Division of Nature Preserves of the Indiana Department of Natural Resources, and one expressing thanks to the host institution. The resolutions were approved for presentation at the General Meeting.

Constitutional Amendments

Duvall Jones moved the approval of four proposed amendments, all of which were published in the Sep tember, 1986, *Newsletter*. A change in Article III, Section 7, authorizing the Treasurer to sign contracts as authorized by the Executive Committee, was approved.

A change in Article VI, Section 4, clarifying the operation of the Budget Committee, was approved.

A new Article V, Section 3, concerning use of Academy trust funds, was approved.

A replacement of Article VI, Section 3, concerning the composition and operation of the Program Committee was tabled.

The approved amendments will be presented to the membership at the General Meeting.

Publications

Benjamin Moulton, chair, reported that the monograph *Butterflies of Indiana*, by Schull and Schull, edited by Eberly, has been given to the IU Press for publication. It should appear in the Fall of 1987. An estimated cost has been given of $33,000.00 for 5,000 copies.

Work is proceeding on two other manuscripts, *The Flora of Indiana* by William Crankshaw, and *Endangered Species of Indiana* by John Whitaker and James Gammon.

The Committee will discuss the impact of publishing the abstracts of papers presented at the Fall meeting as a publication separate from the *Proceedings*.

Editorial Board

Donald Winslow, Editor, reported that the awards established in 1982 for excellence in papers published in the *Proceedings* will be awarded for the first time this year. Five papers were nominated by Section chairs. The winners of the two $150.00 awards are Jeffrey A. Andresen and Robert F. Dale, and John A. Rupp.

Volume 95 of the *Proceedings* is being printed by Western Newspaper Publishing Co., Inc., of Indianapolis. Page proofs are being prepared.

Winslow moved that the Editor be allowed to make an appropriate page charge for excess corrections in proof, in consultation with the Publications Committee. The motion carried.

Science and Society

Alice Bennett, chair, reported that the Committee has arranged a Symposium, "AIDS: Educating the Public" for Saturday, November 15, and has prepared for distribution a booklet about the talks given. The Committee authorized the use of the Academy's name as a sponsor of an *amicus curiae* brief filed in the Supreme Court of the United States in a case involving evolution and scientific creationism.

The Committee has initiated an awards program for graduate students presenting scientific papers at the Fall meeting. Each Section Chair will have the opportunity to identify a graduate student presenter who should receive a membership in AAAS for the coming year.

OTHER BUSINESS

Logo Selection Committee chair Duvall Jones reported that members will be asked to vote on their favorite of eight suggested designs.

Frank Edmondson of the Indiana University Department of Astronomy requested Academy support for the institution of an endowed professorship there in the name of Professor Daniel Kirkwood, distinguished astronomer and a founder of the Academy. Conklin moved that the Resolutions Committee draft a resolution endorsing establishment of a Daniel Kirkwood Professorship at Indiana University. The motion carried.

REPORTS OF OTHER COMMITTEES

Representative to AAAS

Sears Crowell attended the meeting in Philadelphia. Plans to create a Section Y - General Interest, which would be appropriate for state academies, are still under way. He urged appointment of a person concerned with Junior Academy programs.

Representative to Natural Resources Commission

Damien Schmelz attends monthly meetings of the Commission, which sets policies, issues regulations, and grants permits.

Biology Survey

The Committee cosponsors the annual Natural Areas Conference, at IU Northwest and Indiana Dunes this year, New Harmony in 1987. It is developing a list of endangered and threatened bryophytes in Indiana.

Executive Secretary Feasibility

The study is continuing. A trial year seems advisable, if funding can be obtained.

Library

Distribution of Volume 94 of the *Proceedings* has been completed. A total of 801 hardcover and 432 softcover copies were sent. $8,900.00 to be applied to the cost of printing Volume 95 was received from the State Budget Agency.

During 1986, 192 volumes were added to the library's collection, bringing the total to 11,207. Twenty-four new exchange titles were catalogued and added to the OCLC database. 258 interlibrary loan requests were processed.

Membership

New invitation-to-membership brochures have been printed, 6,000 in all. The effort to obtain more corporate members continues.

Speaker of the Year

Dr. Ruth H. Howes of the Department of Physics and Astronomy, Ball State University, has been named Speaker of the Year. The title of her address, to be presented first at the Fall meeting, is "Science and National Security Policy." She will visit five institutions during the year.

Youth Activities

Dr. Mark Whitman of Lafayette is the new Director of the Junior Academy. The Fall meeting will be held concurrently with the meeting of the Academy on November 14.

Dr. Jan Woerner is the new Director of the Indiana Science Olympiad. The 1987 competition will be at Center Grove High School, Greenwood, on March 21.

The second Indiana Science and Engineering Fair will be held at Indianapolis on April 23 and 24. Financial assistance for regional science fairs will be proposed to the Budget Committee.

A grant of $1,200.00 was received as a result of a proposal submitted to the AAAS for the support of high school science research projects.

Respectfully submitted,
Richard L. Conklin, Secretary

INDIANA ACADEMY OF SCIENCE

Fall 1986, Grant Applications Funded

Research Grants Committee Actions

No.	Principal Investigator/ Institution & Dept.	Title	Funded
1.	Amy Berndtson Notre Dame-Biol. Sci.	Characterization and hormonal regulation of proteolytic enzymes . . .	$ 832.00
2.	James Berry Butler-Biol. Sci.	Biogeography of spiders of the Pacific Islands	650.00
3.	Shree Dhawale Biology-Earlham	Analysis of mitochondrial DNA from host specific isolates . . .	750.00
4.	Frank Knight IU-Blmg.-Biology	The onset of normal and endotoxin affected behavioral responses to thermal stimuli	503.00
5.	David Lipke Notre Dame-Biol. Sci.	. . . aspects of the kallikein-kinin and renin-angiotensin systems in rainbow trout	1,000.00
6.	April Mason Purdue-Foods & Nutrition	Bioavailability of selenium to rats from a soy protein based diet	550.00
7.	Cheryl Mason Purdue-Biology	Improving student attitudes toward science-related careers . . .	1,250.00
8.	Kyoungsook Park ISU-Life Sciences	The effects of ascorbic acid on transcriptional activity in aging human diploid fibroblasts	1,062.00
9.	Charles Sanislow Ball State-Psych. Sci.	Mood and interpersonal perceptions of students . . .	205.00
10.	David Schmitt Notre Dame-Biol. Sci.	Orientation of honeybees in earth-strength magnetic fields	645.00
11.	Horst Siewert Ball State-Nat. Res.	Effects of hazardous waste cleanup on aquatic organisms in Finely Creek	285.00
12.	Kathryn Wilson IUPUI-Biology	Tissue culture methods and selection of disease resistant . . . Gladiolus	850.00
		Total—	$8,582.00

INDIANA ACADEMY OF SCIENCE
1986 High School Student Research Proposals Funded

Research Grants Committee Actions

No.	Principal Investigator/ School/City	Title	Funded
1.	Dragica Balc Gavit/Hammond	The Effects of Electrostatics on Callus Growth and Differentiation of Daucus carota	$ 155.00
2.	Pamela Cooper Northside/Muncie	Microbiological Concerns Regarding Home Use of Activated Carbon Filters . . .	165.00
3.	Tom Hamilton Adams/South Bend	An Investigation of Altered Diets on the Mechanisms of Systemic Dissemination of Candida albicans	100.00
4.	Molly Hooten Paoli/Paoli	A Three Year Study into Calcium and Sodium Influx to Selected Tissue	155.00
5.	Deborah Houser E. Noble/Kendallville	The Effect of Enalopril on ANF Levels in Spontaneously Hypertensive Rattus norvegicus	140.00
6.	Dave Kantowitz Harrison/W. Lafayette	Design and Construction of a Computer-Assisted Non-Steady State Crystalizer	125.00
7.	Ann Koons E. Noble/Kendallville	A Study of the Chemotherapeutic Treatment of Specific Types of Cancer . . .	150.00
8.	Sarah Ley Cnt.Noble/Kendallville	The Effects of Smoking on HDL Composition of the Blood	125.00
9.	Matt Moore Harrison/W. Lafayette	A Study of the Effects of Weather Variables on Airborne Particulate Matter in Lafayette, IN	100.00
10.	Andrij Petryna Gavit/Hammond	Parabolic Solar Water Heater Integrated with a Gas Furnace	150.00
11.	Ted Scheel Adams/South Bend	The Possible Prolonged Enhancement of Physiological Processes with Vitamin-Mineral Supplementation . . .	72.00
12.	Julie Stante Adams/South Bend	Possible Effect of Imposed Stress Due to Sleeplessness on the Immune Response of Laboratory Mice	69.00
		Total—	$1,506.00

INDIANA ACADEMY OF SCIENCE
GENERAL MEETING

November 14, 1986

MINUTES

The meeting was called to order by President Ernest E. Campaigne at 1:20 p.m. in Ransburg Auditorium, University of Indianapolis.

Dr. Gene E. Sease, President of the University, welcomed the Academy to the campus.

Dr. Daniel Briere, Assistant Professor of Spanish at the University, delivered a brief review of the early history of science under the title, "The Medieval Paradigm Then and Now."

Secretary Richard Conklin reviewed the actions taken and reports given at the meeting of the Council of the Academy.

Treasurer Duvall Jones reported that the finances of the Academy are sound. He announced that Life Membership is available for a single payment of $300.00.

Fay Daily, Necrologist, reviewed the lives of five members whose deaths became known during 1986:

Donald W. Ash
Henry Shirley Rothrock
Ralph Wayne Stark
Theodore Torrey
Harold E. Wolfe

A minute of silence was observed in their memory.

Duvall Jones presented three amendments to the Constitution which had been published in the *Newsletter* and approved by the Council:

1) Article III, Section 7. "Treasurer. The Treasurer shall have been a member of the Academy for at least three years. The Treasurer shall have custody of all funds of the Academy except as otherwise provided, issue statements, receive payment of dues and assessments, and pay bills chargeable to the Academy; sign contracts on behalf of the Academy as authorized by the Executive Committee; promptly submit the Academy's financial records for audit; report to the Council annually on the financial standing of the Academy; and be responsible for filing such financial reports as may be required by state and federal offices."

2) Article VI, Section 4. "The Budget Committee of the Academy shall consist of the following who will hold the specified positions for the next calendar year: the retiring Secretary and Treasurer (in the year in which these offices change), the Director of the Junior Academy of Science, chairs of the Program Committee, Library Committee, Youth Activities Committee, Academy Foundation Committee, Publications Committee, Science and Society Committee, and Research Grants Committee. Others may be present by invitation. The Budget Committee shall meet by December 15th each year to establish the operating budget and to allocate trust income for the following year. Revisions of the budget or allocations of trust income may be made by the Budget Committee at the Spring or Fall meeting."

3) Article V, Section 3. "Income from the Academy trust funds is to be used primarily for the support of research by members of the Academy, including publication of research reports, monographs, and administrative expenses associated with these activities. Allocations of trust income are made by the Budget Committee. Commitment to publish a monograph or other research work requires approval by the Publications Committee and allocation of adequate funds by the Budget Committee; contracts must have approval of the Council prior to signing. All or any part of the income for any given year

may be applied to any purpose other than research with the recommendation of the Executive Committee and the consent of both the Research Grants Committee and the Academy Foundation Committee, and approval of the Council. A majority of the members present and voting at the annual meeting of the Academy also must give approval."

All three new or revised amendments were adopted.

Donald Winslow, Editor of the *Proceedings of the Academy* presented $150.00 awards for excellence of articles published in the *Proceedings* to Jeffrey Andresen and Robert F. Dale, authors of "Climatic Data Bases," and to John A. Rupp, author of "The Backbone Limestone (Lower Devonian), a Potential Reservoir in Southern Indiana."

Marvin Carmack, chair of the Committee on Fellows, presented the names of the following nominees:

Malcolm Harold Chisholm
  Distinguished Professor of Chemistry, Indiana University
Gary E. Dolph
  Professor of Botany, Indiana University Kokomo
Uwe J. Hansen
  Professor of Physics, Indiana State University
Richard Jensen
  Associate Professor of Biology, St. Mary's College
Dennis Gail Peters
  Herman T. Briscoe Professor of Chemistry, Indiana University

All five were elected, and certificates were presented to those who were present.

The Secretary read the report of the Committee on Emeritus members, presenting the following applicants:

D.M. Downie, Lafayette
Charles B. Heiser, Bloomington
Kenneth E. Nichols, Valparaiso
Phillip A. Orpurt, North Manchester
John B. Patton, Bloomington
William G. West, Brazil

All were elected to Emeritus membership.

Alice Bennett, Chair of the Nominating Committee, presented the following slate for 1987:

President-Elect: Wilton N. Melhorn
Research Grants Committee: Benjamin Swartz, Jr.
Bonding Committee: John Whitaker

The Secretary was instructed to cast a unanimous ballot for those nominated.

President Campaigne requested members to comment on the booklet of abstracts of papers presented at the Section meetings.

Charlotte Boener, Chair of the 1987 Program Committee, announced that the Spring Meeting will be held at McCormick's Creek State Park on April 10 and 11. The Fall Meeting will be at Indiana State University on November 6 and 7.

William Davies, Resolution Committee Chair, presented several resolutions:

Two resolutions were approved by the Council:

1) WHEREAS: The Indiana Academy of Science is deeply grateful to the University of Indianapolis for its invitation to hold the 102nd annual meeting on its campus; and

WHEREAS: The administrative, faculty, staff and students of the University of Indianapolis have cooperated admirably in providing us their facilities and support for this 102nd annual meeting; be it

RESOLVED: That the Academy members and guests here assembled express their sincere appreciation to Dr. Gene E. Sease, President of the University, for all the courtesies and assistance that have been extended to the Academy during this meeting. We are especially grateful to Drs. John Batey and Gerald Zimmerman, who served as Co-Chairmen of the Program Committee, and other participating faculty members of the University of Indianapolis for the arrangements of the entire program and for the comfort and conveniences provided our members. We also express our sincere thanks to all members who organized and participated in all aspects of the 102nd annual meeting.

2) WHEREAS: The Indiana Academy of Science is directed, constitutionally, to promote scientific research and the diffusion of scientific information in a scholarly manner, and has interest in improving science education, and in informing the general public of the level of scientific knowledge regarding natural areas and rare species; and

WHEREAS: The Indiana Division of Nature Preserves (Department of Natural Resources) and The Nature Conservancy, in following their mandates to protect natural areas and to collect and interpret data regarding elements of Indiana's natural heritage, are pursuing goals that coincide in this area with those of the Academy, and

WHEREAS: The Indiana Division of Nature Preserves and The Nature Conservancy are jointly seeking to increase and enhance support for their program of natural area acquisition and stewardship through the recently enacted Indiana Natural Heritage Protection Campaign (a public-private conservation effort designed to generate $10 million to complete the Nature Preserve System); it is therefore

RESOLVED: That the Indiana Academy of Science supports the Indiana Natural Heritage Protection Campaign and the efforts of the Indiana Division of Nature Preserves and The Nature Conservancy to complete the Indiana Nature Preserve System; and it is further

RESOLVED: That the Indiana Academy of Science and the Indiana Division of Nature Preserves and The Nature Conservancy, should promote and develop a close working relationship in recognition of their common goals in biological science, in nature study, in education, and in natural area protection.

One was approved in principle by the Council; the exact wording was prepared after the Council meeting.

3) WHEREAS: Daniel Kirkwood was a founding member of the Indiana Academy of Science, and the first Honorary Member of the five who have been so honored; and

WHEREAS: 1986 is the 100th anniversary of Daniel Kirkwood's retirement from the Faculty of Indiana University after thirty years of distinguished service, and

WHEREAS: The "Kirkwood Gaps" in the orbits of the asteroids between Mars and Jupiter, discovered by Daniel Kirkwood in 1866 at Indiana University, are still referred to by this name in present day research literature; and

WHEREAS: Daniel Kirkwood was a great teacher, beloved by his students and the people of Bloomington; it is therefore

RESOLVED: That the Indiana Academy of Science strongly endorses the proposal to establish a DANIEL KIRKWOOD PROFESSORSHIP OF ASTRONOMY at Indiana University, and urges the administration of the University to take all necessary steps to bring this Professorship into being in the near future.

These three resolutions were adopted without debate.

A group of resolutions were presented which had not been presented to the Council:

WHEREAS: The Indiana Academy of Science is directed, constitutionally, to promote scientific research and the diffusion of scientific information in a scholarly manner, and has interest in improving science education in the public schools, and,

WHEREAS: Education in the natural sciences is necessary for the full participation of individuals in our technological society, for modern industrial and economic development, and for the strength and unity of our nation, be it

RESOLVED: That the Indiana Academy of Science urgently recommends that science education be developed into an integral part of curricula in elementary education, and

WHEREAS: Many elementary teachers are uncomfortable with science and may be inadequately prepared to teach science, be it further

RESOLVED: That this effort include the development of specialized elementary science teachers and adherence to state requirements for teaching of science by local school corporations.

WHEREAS: Textbook publishing companies are being consolidated into large conglomerates often without an educational orientation, and

WHEREAS: Various special interest groups are attempting to dictate, either directly or indirectly, the science curricula of our public schools, be it

RESOLVED: That the Indiana Academy of Science supports the continued existence of the State Textbook Adoption Committee and its role in the initial selection of textbooks for students in the public schools of Indiana. Be it further

RESOLVED: That the Indiana Academy of Science, with a membership of practicing scientists and mathematicians, will recommend qualified members to serve on the State Textbook Adoption Committee.

WHEREAS: It has been found that the most significant factor in superior science and mathematics instruction is the classroom teacher, and

WHEREAS: There are differences in teacher preparation among our teacher education institutions with respect to entry requirements and prescribed courses of study, be it

RESOLVED: That the Indiana Academy of Science recommend to the Superintendent of Public Instruction that all teacher education institutions within the State of Indiana adhere to the Standards for the Preparation and Certification of Teachers of Science in grades K-12 as adopted by the National Science Teachers Association.

A motion to table the textbook resolution was defeated. The set were then approved by a voice vote.

The business meeting adjourned and the Speaker of the Year, Ruth H. Howes, Professor of Physics and Astronomy at Ball State University, spoke to the title, "Science and National Security Policy." She described personalities and procedures she had encountered during a year as a consultant to the Arms Control and Disarmament Administration.

The afternoon program ended at 3:00 p.m.

Respectfully submitted,
Richard L. Conklin, Secretary

INDIANA ACADEMY OF SCIENCE
BUDGET COMMITTEE

December 6, 1986

MINUTES

The meeting was called to order by Stanley Burden at 9:15 a.m. in the Auditorium of the Indiana State Library. Those present and their areas of interest were: Charlotte Boener (Program), Austin Brooks (Research), Stanley Burden (1987 President), E.E. Campaigne (1986 President), Richard Conklin (Secretary), William Daily (Academy Foundation), Duvall Jones (Treasurer), Benjamin Moulton (Publications), Holly Oster (Library), Virginia Rhodes (Youth Activities), David Squiers (Science and Society), Mark Whitman (Junior Academy), and Donald Winslow (Editor).

Minutes of the meeting of 1985 were read and approved.

E. Campaigne reported for the logo committee. Contact has been made with Mr. James Gray of Stone Cabin Design, Gosport, IN, who specializes in logos. He outlined three options under which he could operate. The committee will request him to give an estimate of the cost to the Academy based on his using the suggested logos submitted by the membership as a starting point for his design of a new logo. The Secretary will order stationery for 1987 using the present letterhead style.

Stanley Burden distributed a summary of responses to the survey on members' response to the Abstract booklet at the Fall meeting. Partly on the basis of this response and partly on other considerations, for the Fall, 1987, meeting the program and abstracts will be printed in the same booklet and mailed well before the meeting. This decision and what it means to members presenting papers will be discussed in the *Newsletter*. This is a second experimental year; the abstracts will also be printed in the 1987 *Proceedings*. If the members respond favorably to this and to another questionnaire to be distributed later, the abstracts booklet will be considered the official publication of the abstracts that then will not be printed again in the *Proceedings*.

Due to an oversight, there is a vacancy on the Academy Foundation Committee, John Ricketts' term having expired. President Burden appointed E.E. Campaigne to a three-year term on that committee. The action was endorsed by approval of a motion by Brooks.

Treasurer Duvall Jones presented the proposed budget for 1987, and discussion of several matters arose as specific items were reached. He called attention to the reorganization of the allocations for Management and General Expenses, which now designate line items for particular purposes rather than for particular offices. The Treasurer will be responsible for informing officers if their expenditures are threatening to exceed the budget.

The Executive Committee had requested the budget committee to consider the expenses incurred by section chairs in mailings to their members. After considerable discussion of present practices, the following policy was adopted:

1. The call for papers will continue to be made in the *Newsletter*.
2. Section chairs who wish to communicate with their members should arrange with their own institutions for financing the mailing.
3. In case of hardship, funds can be allocated by the Treasurer from the Executive Committee Contingency Fund.
4. Need for such mailings might be reduced if members would notify section chairs of their intent to publish. A form for this purpose is to be designed for inclusion in the *Newsletter*.

The Secretary is to notify section chairs of this policy.

Charlotte Boener presented itemized estimates of the costs of the Spring and Fall meetings. Moulton moved the allocation of $2000 from the John S. Wright Fund for the printing of the *Abstracts*. The motion carried.

Virginia Rhodes spoke to the budget for Youth Activities. The major change requested is an addition of $3000 so that the Academy can allocate $250 to each of the Regional Science Fairs to help defray the costs of affiliation with the International Science Fair. $300 was also requested to help pay for awards and other incidental expenses for the new Science Olympiad program.

Mark Whitman reported that participation in the Junior Academy has increased from fifteen schools to seventy-five, and that sponsors will become members of the Academy. Because of this increased activity and a possible loss of revenue from a corporate sponsor, he requested the increase of the Junior Academy allocation to $2500. A final figure of $2000 was approved with the understanding that the Contingency Fund could be used if the corporate support is indeed reduced.

Upon motion by Jones, the registration for the Fall meeting was set at $5 for members, including clubs, and $7 for non-members.

Upon motion by Campaigne, $3000 was approved for the purchase of a personal computer and accessories for use in maintaining membership records and providing dues cards and mailing labels.

Benjamin Moulton spoke on behalf of the Executive Secretary Feasibility Committee. There was general support for continuing the study of the value of such an office and possible means of funding it. Campaigne spoke in favor of using some of the research money allocated from the John S. Wright Fund for administrative purposes. He suggested that the Foundation Committee might consider this and make a recommendation to the Council.

Jones moved the transfer of $572.25 from reserve funds to the Administered Account for reprints. The motion carried.

Jones moved the transfer of $10,570 from reserve funds to balance the budget, and the adoption of the budget as thus balanced. The motion carried.

Austin Brooks spoke for the Research Grants Committee. A new brochure is being published, and two modifications seem desirable:

1. Increase the upper limit on an individual grant from $1500 to $2500.
2. Remove the word "exceptional" from the conditions on grants for equipment.

The two changes were approved on motion by Campaigne. The amount budgeted for grants was increased from $25,000 to $30,000.

Jones moved the approval of allocations from Trust Funds. The motion carried.

The meeting was adjourned at 2:00 p.m.

Respectfully submitted,
Richard L. Conklin, Secretary

INDIANA ACADEMY OF SCIENCE
1987 Budget

Anticipated Income

Academy Accounts		
Dues		$15,000.00
Contributions		250.00
Interest		2,500.00
Reserve Funds		10,570.00
	Total	$28,320.00

Expenditures

Academy Accounts		
Management & General Expenses		
Executive Committee Contingency Fund		$ 2,200.00
Office Supplies		700.00
Telephone		100.00
Postage and Shipping		1,700.00
Insurance and Fees		250.00
Office Services		900.00
Membership Services (printing, etc.)		500.00
Travel ($200-PR)		400.00
CPA Fees		550.00
Equipment (computer)		3,000.00
Program Services		
Editorial Board Awards		300.00
Newsletter		900.00
Public Relations		500.00
Meetings: Printing & Mailing (Abstracts)		1,670.00
Youth Activities Committee		3,000.00
Science Olympiad		300.00
Speaker of the Year		700.00
AAAS Representative		250.00
Biological Survey Committee		1,700.00
Science Education Advisory Committee		200.00
Science & Society Committee		1,600.00
Transferable to Administered Accounts		
Junior Academy		2,000.00
Meetings: Meals & Registrations		0.00
Reprints		2,500.00
Library Binding		1,100.00
Publications: Mailing		1,300.00
Science Talent Search		0.00
	Total	$28,320.00
Trust Funds		
Anticipated Income and Expendable Funds		
IAS Fund	(00430-00-0)	$ 2,900.00
John S. Wright Fund	(00430-01-9)	41,000.00
Invested Income Account	(00430-02-8)	131,000.00
	Total	$174,900.00

Approved Expenditures	
Fiduciary Fees	$ 7,000.00
Research Grants for Senior Academy Members	30,000.00
Research Fellowship for High School Teachers	5,000.00
Research Grants for High School Students	600.00
Publications	
Abstracts	2,000.00
Proceedings (Volume 95)	8,000.00
Climate of Indiana	15,000.00
Butterflies of Indiana (1987)	35,000.00
Endangered Species (1987)	7,000.00
Flora of Indiana (Crankshaw)	8,000.00
Symposium Booklet	1,500.00
Research Grants Brochure & Expenses	800.00
Total	$119,900.00

Additional Income

Administered Accounts (dedicated, unbudgeted funds)	
Reprints	2,700.00
Junior Academy (IBM)	1,400.00
Science Talent Search	2,500.00
High School Research	1,200.00
Meetings: Meals & Registration	4,000.00
Total	$ 11,800.00

INDIANA ACADEMY OF SCIENCE
Financial Report
1 January — 31 December 1986

I. ACADEMY ACCOUNTS

	Income	Budgeted	Expenditures	Budgeted
Dues	$15,448.00	$13,800.00		
Contributions	245.00			
Interest	2,877.11	2,100.00		
Reserve funds - general		2,100.00		
Transfer to Administered Account (Reprints)	(572.25)			
Management & General expenses				
President				
General Office			600.00	600.00
President's Contingency Fund			157.80	250.00
Secretary			254.64	400.00
Treasurer			1,381,67	1,550.00
Editor			300.00	750.00
Membership Committee			973.95	1,500.00
Officers Travel			125.00	150.00
CPA Fees			525.00	550.00
Program Services				
Newsletter			523.44	900.00
Public Relations			500.00	500.00
Programs for meetings			2,499.49	2,500.00
Junior Academy			1,196.23	1,200.00
Youth Activities Committee			1,222.72	1,250.00
Speaker of the Year			700.00	700.00
Section Chairs			41.91	50.00
AAAS Representative			300.00	300.00
Biological Survey Committee			1,500.00	1,500.00
Science and Society Committee			279.62	1,600.00
Miscellaneous	40.00		40.00	100.00
Transfers to Administered Accounts				
Library binding			1,500.00	1,500.00
Publications: Mailing			900.00	900.00
Research grants			2,987.63	2,987.63
TOTALS	$18,037.86	$18,000.00	$18,509.10	$21,737.63

II. ADMINISTERED ACCOUNTS

	January 1 Balance	1986 Transfers & Income*	1986 Transfers Expenditures	31 December Balance
Junior Academy of Science	$ 0.00	$ 1,600.00(I)	$ 1,596.00	$ 4.00
J.S. Wright Library Fund	134.28	(64.09)(T_3)	70.19	0.00
Lilly Library Fund	7,003.52	64.09(T_3)	15.95	7,051.66
Library Binding	3,912.20	1,500.00(T_1)	1,585.90	3,826.30
Meeting Fees & Expenses	852.68	7,827.47(I)	7,002.93	1,677.22
Publications				
Printing: *Proceedings*	1,952.89	20,319.05(T_2)	20,319.05**	1,952.89
Monographs		599.20(T_2)	599.20	
Mailing: *Proceedings*	753.46	900.00(T_1)	1,098.41	555.05
Monographs				
Sale of Publications	5,144.24	1,157.58(I)	307.04	5,994.78
Reprints (Volumes 94 & 95)	0.00	2,888.70	3,273.59	187.36
Transfer from reserves		572.25(T_1)		
Research Fellowships	149.25	3,500.00(T_2)	3,500.00	149.25

Research Grants - Senior	−3,765.00	22,646.00(T_2) 2,987.63(T_1) 1,200.00(I)	23,068.63	0.00
Research Grants - High School	0.00	300.00(I)	0.00	300.00
Science Talent Search	2,238.14	2,577.00(I)	3,440.60	1,374.54
TOTALS	$18,375.66	$70,574.88	$65,877.49	$23,073.05

*I: Income from external sources.

T_1: Transfer from Academy Accounts. T_2: Transfer from Academy Trust Funds.

T_3: Transfer from Wright Library Fund to Lilly Library Fund.

** The State of Indiana paid an additional $8,900.00 toward printing of the *Proceedings*.

III. SUMMARY

	Academy Accounts	Administered Accounts	Total
Balance: 1 January 1986	$15,060.18	$18,375.66	$33,435.84
1986 Income	18,037.86	70,574.88	88,612.74
1986 Expenditures	18,509.10	65,877.49	84,386.59
Balance: 31 December 1986	$14,588.94	$23,073.05	$37,661.99

IV. BANK BALANCES (as of 31 December 1986)

Super NOW Account	
Northwest National Bank, Rensselaer, IN; Acct #21-0497-4	$ 2,884.36
Hi-Fi Checking Account	
Northwest National Bank, Rensselaer, IN; Acct #70-032504	10,232.62
Savings Accounts	
Farmers National Bank, Remington, IN-CD #2408862	2,421.76
#302641	2,421.76
State Bank of Rensselaer, IN-CD #100211766	8,229.59
Bank One, Lafayette, IN CD #66594185	5,000.00
Indiana Federal S&L, Rensselaer, IN CD #10-0140111	3,370.56
Northwest National Bank, Rensselaer, IN CD #11985	3,101.34
TOTAL	$37,661.99

V. SUMMARY OF TRUST FUNDS

	Research Acct. (430-00-0)	Wright Fund (430-01-9)	Invested Income (430-02-8)
Assets (1 January 1986)			
Cash	$ 471.51	$ −3,132.55*	$ 8,793.73
Tax Value of Investments	39,228.68	372,702.92	125,145.72
Tax Value of Account	$39,700.19	$ 369,570.37	$133,939.45
Income and Transfers			
Dividends	646.20	26,812.00	0.00
Interest	2,224.93	15,444.21	10,298.08
Income from Sales	0.00		0.00
Transfer from Wright Fund		0.00	36,888.63
Expenditures and Transfers			
Fiduciary Fees	−12.26	−5,941.95	−29.73
Transfer to Invested Income	0.00	−36,888.63	0.00
Distributions to Progams	−300.00	0.00	−47,064.25

Assets (31 December 1986)

Cash	188.19	−4,264.19*	5,546.54
Tax Value of Investments			
Short Term Investments	3,800.00	52,100.00	5,100.00
Bonds	25,742.19	152,439.24	120,311.11
Stocks	12,181.50	227,996.70	0.00
Tax Value of Account	$41,911.08	$ 428,271.75	$130,957.65
Market Value of Principal	$49,528.32	$1,220,594.56	$131,932.34

*Negative balances due to computer error; corrected on 2 January.

VI. NOTES

Membership

1,188 memberships for 1986 as of 31 January 1987

48	sustaining members
668	members
190	associate members
79	student members
4	honorary members
6	life members
109	emeritus members
79	clubs
5	corporate members
5	members deceased (included above)
122	on file from 1985 not paid for 1986
124	new and reinstated members in 1986
102	members and clubs dropped for nonpayment of 1985 dues

Dues structure for 1986:

$ 5.00	for clubs and student memberships
10.00	for associate memberships
15.00	for members
25.00	for sustaining memberships
300.00	for life memberships
150.00-500.00	corporate memberships
50.00-100.00	institutional memberships

Reprints: All authors of papers in Volume 94 of the *Proceedings* have paid for the reprints which they ordered. Cost of the reprints to the Academy was $3,273.59. Authors paid the Academy $3,356.20 for reprints.

Publications: Sales of reprints, monographs and *Proceedings* in 1986 totaled $4,046.28.

Research Grants: Funds totaling $23,346.00 have been awarded.

Grants Received: The State of Indiana contributed $8,900.00 toward publication of the Academy *Proceedings*. Kappa Kappa Kappa Sorority made $1,500.00 available for awards and expenses for the Science Talent Search for Indiana high school students.

The American Association for the Advancement of Science granted $1,200 to be used by high school students for research.

Public Service Indiana provided funds for a teacher's workshop in conjunction with the Science Talent Search of 1986.

The John S. Wright Fund, one of the Academy's trust accounts, supports most of the Academy's research grant programs, as well as research-related publications such as the *Proceedings* and monographs.

VII. BUDGET FOR 1987

The following budget was approved by the Budget Committee in its meeting of 6 December 1986.

Anticipated Income		
Academy Accounts		
Dues		$ 15,000.00
Contributions		250.00
Interest		2,500.00
Reserve Funds		10,570.00
	Total	$ 28,320.00
Expenditures		
Academy Accounts		
Management & General Expenses		
Academy Development Fund		$ 2,200.00
Office Supplies		700.00
Telephone		100.00
Postage and Shipping		1,700.00
Insurance and Fees		250.00
Office Services		900.00
Membership Services (printing, etc.)		500.00
Travel		400.00
CPA Fees		550.00
Equipment (computer)		3,000.00
Program Services		
Editorial Board Awards		300.00
Newsletter		900.00
Public Relations		500.00
Meetings: Printing & Mailing (Abstracts)		1,670.00
Youth Activities Committee		3,000.00
Science Olympiad		300.00
Speaker of the Year		700.00
AAAS Representative		250.00
Biological Survey Committee		1,700.00
Science Education Advisory Committee		200.00
Science & Society Committee		1,600.00
Transferable to Administered Accounts		
Junior Academy		2,000.00
Meetings: Meals & Registrations		0.00
Reprints		2,500.00
Library Binding		1,100.00
Publications: Mailing		1,300.00
Science Talent Search		0.00
	Total	$ 28,320.00

Trust Funds

Anticipated Income and Expendable Funds as of 1 January 1987		
IAS Fund	(00430-00-0)	$ 2,900.00
John S. Wright Fund	(00430-01-9)	41,000.00
Invested Income Account	(00430-02-8)	131,000.00

Approved Expenditures	
Fiduciary Fees	$ 7,000.00
Research Grants for Senior Academy Members	30,000.00
Research Fellowship for High School Teachers	5,000.00
Research Grants for High School Students	600.00
Publications	
Abstracts	2,000.00
Proceedings (Volume 95) (1987)	8,000.00
Climate of Indiana	15,000.00
Butterflies of Indiana (1987)	35,000.00
Endangered Species (1987)	7,000.00
Flora of Indiana	8,000.00
Symposium Booklet (1987)	1,500.00
Research Grants Brochure & Expenses	800.00
Total	$119,900.00

Respectfully submitted,

Duvall A. Jones, Treasurer

We, the undersigned, have audited the Treasurer's records for the Indiana Academy of Science for the year 1986 and have found them to be accurate and in order.

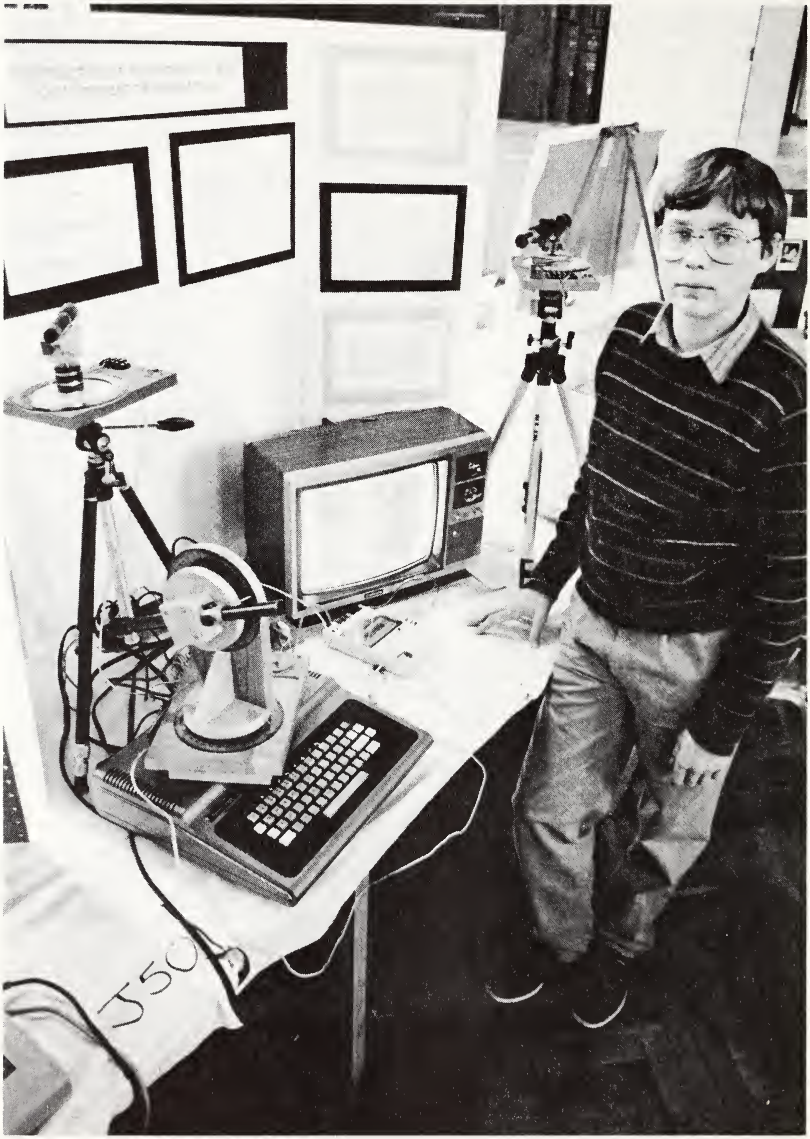
Andrew G. Mehall

John Ricketts

________________, 1987

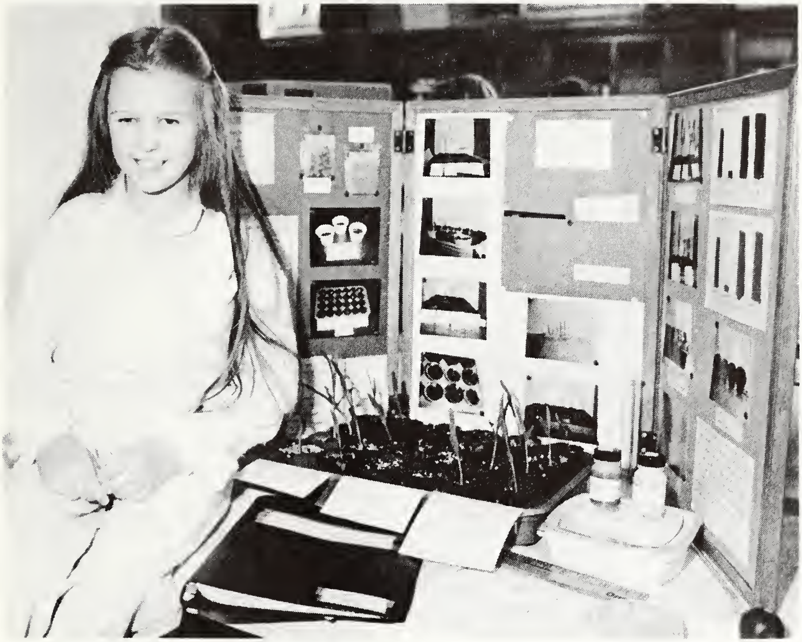
________________, 1987

John Huffman Wins in Science Fair



BLOOMINGTON, Ind.—John Huffman, an eighth-grader at Bloomington Tri-North Middle School, won first prize in the junior division's mathematics and computers category of the South Central Indiana Regional Science and Engineering Fair, held Saturday (March 22) at Indiana University. Huffman's project was titled "Construction of an Instrument for Computerized Triangulation." His teacher is Donald Bevis. Huffman was one of two overall winners in the junior division who will advance to the statewide Hoosier Science Fair at the Indianapolis Children's Museum April 17-19.

Niki Cummings Wins in Science Fair



BLOOMINGTON, Ind.—Niki Cummings, a seventh-grader at Edgewood Junior High School in Ellettsville, won first prize in the junior division's botany category at the South Central Indiana Regional Science and Engineering Fair Saturday (March 22) at Indiana University. Her project was titled "Is the Plant Hormone Auxin Necessary for Growth?" Her teacher is Barbara Engle. Cummings was one of two overall winners in the junior division who will advance to the statewide Hoosier Science Fair at the Indianapolis Children's Museum April 17-19.

TUDY OF CHLOROPHYLL CONTENT IN SOYBEAN LEAVES
AS AFFECTED BY GENETIC DIVERSITY
PROCEDURES
PURPOSE
RESULTS

Professor Austin Brooks, a member of the Science Talent Search Committee, questions Christina Fong from Wm. Henry Harrison High School, West Lafayette, about her research, A Study of Chlorophyll Content in Soybean Leaves as Affected by Genetic Diversity.

ANNUAL REPORT, YOUTH ACTIVITIES

Hoosier Science and Engineering Fair

Seventy-two Indiana students competed for awards in April in the first annual Hoosier Science and Engineering Fair.

Entrants in the event, held at the Indianapolis Children's Museum, were pupils in the seventh through 12th grades who had won top honors in 12 Indiana Regional Science and Engineering Fairs. The statewide competition was sponsored by the Indiana Science Education Fund.

Indiana professional scientists judged the students' projects during the three-day run of the program. Evaluations were based mostly on interviews with the entrants and the innovativeness of their work.

More than $100,000 in scholarships, science-related trips, medals, cash, certificates and other awards were presented. The awards were given by more than 50 government agencies, colleges and universities, and professional organizations.

Two overall champions at the fair were chosen to enter their projects in the International Science and Engineering Fair, held in May at Fort Worth, Texas. Also awarded the trips were the sponsoring teachers of the winners.

The two state science fair winners joined 24 other Indiana students, chosen at regional fairs, in competing in international judging in Texas.

Four students were chosen at the Hoosier Science Fair to receive scholarships from the Indiana Science Education Fund. The winners were:

James Gibson, Harrison High School, West Lafayette (sponsoring teacher: Dr. Mark Whitman).

Laura A. Hunckler, Central Catholic High School, Lafayette (sponsoring teacher: Patricia Mason).

Donald B. Marti, Adams High School, South Bend (sponsoring teacher: Nevin Longenecker).

Mark D. Owens, Marquette High School, Michigan City (sponsoring teacher: Nevin Longenecker).

Indiana Science Talent Search

Report from Donald R. Winslow, Director of the 39th Annual Indiana Science Talent Search, to: Youth Activities Committee and Indiana Academy of Science Council
Spring Meeting, Spring Mill Inn, Mitchell, Indiana, April 25, 1986

Fifty-one students, an increase of about 7% over last year, participated in the 39th Annual Science Talent Search. Twenty four students were declared *Finalists* by the Committee and were invited to participate in the Honors Program the weekend of March 7-8, 1986 at the Medical Center Union Building, Indiana University-Purdue University at Indianapolis.

The activities of the Talent Search were funded at the $1,500.00 level by Kappa Kappa Kappa. In addition to this amount of money, Mae-Mae Shieh of Wm. Henry Harrison High School, West Lafayette and Craig Claussen of Kouts High School each were awarded $1,000 scholarships which must be used at an Indiana four-year school of higher education. Elizabeth Chilcott, State Philanthropy Chair, represented Kappa Kappa Kappa, Inc.

After all of these years, a new dimension, the Public Service Indiana Science Symposium, was added to the weekend activities. This program was designed to invite "new" teachers to the Honors Program and to provide them with ideas for sponsoring students in future talent searches. PSI provided a grant of $800.00 to fund this activity. Special presentations "Why Encourage Students to Conduct Science Investigations?" by Nevin Longenecker; "How Do You Get Started? Where Do You Get Ideas?" by Virginia Rhodes; and "Ideas for High School Science Projects in Chemistry or Physics Using On-Line Microcomputers" by Stanley Burden, President-elect of IAS, were the highlights of the symposium. Sandra McCrocklin, Educational Service Representative, represented Public Service Indiana.

Seventy-two persons attended the Honors Luncheon on Saturday. George Hudock, Associate Professor of Biology, Indiana University, Bloomington, presented the main address: "Current Application of Diagnostic Genetic Techniques."

Next year's Honors Weekend, the 40th, is scheduled for March 6-7, 1987. Deadlines for the submission of research papers is December 15, 1986.

Participants in the 1986 Public Service Indiana Science Symposium

Priscilla Costello	Terre Haute South Vigo High School
Gordon Goodnight	Hagerstown Junior-Senior High School
Steve Makurat	Brown County High School
John Reisert	Salem High School
Karen Richard	Plainfield Junior and Senior High School
Mike Riggle	Bloomington High School South
Richard Schuley	Seymour High School
Keith Shafer	Lawrence Central High School

The Indiana Science Talent Search Committee

Austin Brooks, Department of Biology, Wabash College
Russell Coverdale, Department of Physics, Purdue University
Jo Ann Jansing, Division of Natural Sciences, IU-Southeast
Alfred Schmidt, Department of Mathematics, Rose-Hulman Inst. of Technology
Harold Zimmack, Department of Zoology, Ball State University
Donald Winslow, Director, Office of School Programs, IU-Bloomington

"Winners" in the 39th Indiana Science Talent Search
March 7-8, 1986

Bloom, Sally, R.R. 1, Kendallville, IN 46755. A Comparative Study in Relation to Histoplasma capsulatum in Mus Muscularis (Albino Mouse). East Noble High School, Kendallville. Sponsoring Teacher: Virginia Rhodes.

Call, Edward, R.R. 3, Albion, IN 46701. The Effects of Acid Precipitation on the Growth and Oxygen Production of Cultured Scenedesmus Algae. Central Noble High School, Albion. Sponsoring Teacher: Harold Sollenberger.

Claussen, Craig, 718 Elizabeth Street, Kouts, IN 46347. Photometric Studies of TX Piscium and Alpha Aurigae. Kouts High School, Kouts. Sponsoring Teacher: James Stone. Kappa Kappa Kappa Scholarship Winner.

Gibson, James, 2504 Derbyshire Court, West Lafayette, IN 47906. Factors Affecting Salivary Cortisol Levels in Trained Adolescent Athletes. Wm. Henry Harrison H.S., West Lafayette. Sponsoring Teacher: Mark Whitman.

Jansen, Douglas, 244 Burnam Street, Kendallville, IN 46755. Environmental Toxicity Testing: Phase II. Secondary Studies with Ethylene Dibromide and a Xenopus Indicator System. East Noble High School, Kendallville. Sponsoring Teacher: Virginia Rhodes.

Ma, Alvina, 2608 W. Purdue, Muncie, IN 47304. The Relative Importance of Chemical and Behavioral Inhibition in Rana catesbieana. Northside High School, Muncie. Sponsoring Teacher: Susan McConnell.

Meyer, Hertha, R.R. 2, Box 329, Kendallville, IN 46755. Cytospora cincta Infection of Peach Trees. East Noble High School, Kendallville. Sponsoring Teacher: Virginia Rhodes.

Owens, Mark (NW), Box 54, Michiana, New Buffalo, MI 49117. Real Time Transmission Holographic Interferometry: Determination of Nanometric Movement in Transparent Medium as Applied to Water Channel Flow Visualization in Various Test Specimens. Marquette High School, Michigan City. Sponsoring Teacher: Dean Christakis.

Shieh, Mae-Mae, 4912 Hawthorne Ridge, West Lafayette, IN 47906. The Characterization of an Acetyl-CoA Carboxylase Related Protetin. Wm. Henry Harrison H.S., West Lafayette. Sponsoring Teacher: Mark Whitman. Kappa Kappa Kappa Scholarship Winner.

Swain, Sheryl (N), 314 E. 650 N., West Lafayette, IN 47906. Development of an Ultrafiltration Fiber for the Removal of Subcutaneous Tissue Fluid with Possible Applications Toward a Constant Blood Glucose Monitoring System. Wm. Henry Harrison H.S., West Lafayette. Sponsoring Teacher: Mark Whitman.

Tanner, Martha, 628 S 300 W, Kokomo, IN 46902. The Use of Cobalt (III) Octahedral Complexes in Ceramic Glazes for the Achievement of a Variety of Spectral Colors. Kokomo High School, Kokomo. Sponsoring Teacher: Jerry Cook/Gillette.

Winicur, Zev, 1802 Dorwood Drive, South Bend, IN 46617. The Possible Concomitant Effects of Ragweed Pollen and Burned Leaves on Allergenic Response in Laboratory Mice. John Adams High School, South Bend. Sponsoring Teacher: Nevin Longenecker.

Wolven, Charles, 3202 43rd Street, Highland, IN 46332. Concentrations of PCBs in Damaged Human Liver Tissue. Highland Sr. High School, Highland. Sponsoring Teacher: Herb Schmidt.

(N) — National Finalist (1 of 300)
(NW) — National Winner (1 of 40 in the United States)

Necrology

Fay Kenoyer Daily, Butler University

Donald W. Ash

Louisville, Kentucky — Columbus, Ohio
August 16, 1945 — May 21, 1986

Dr. Donald W. Ash succumbed to cancer in Columbus, Ohio, May 21, 1986. He was an assistant professor at Indiana State University from 1979 to 1985, but left for a position at Battelle Memorial Institute which is dedicated to industrial research. He died shortly thereafter. It was August 16, 1945 when Dr. Ash was born at Louisville, Kentucky. He majored in Geology at Purdue University where in 1972 he received a B.S. Degree and at the State University of New York, Binghamton where he was an assistant and teaching assistant and was recipient of a Ph.D. Degree in 1979.

After receiving his doctorate, he taught Stratigraphy and Sedimentation at DePauw University where he was assistant professor and he was also an assistant professor at Indiana State University. He received tenure at Indiana State in 1980. His experience was varied. Among other things, he was an assistant professor at Indiana University in 1978 teaching field methods at a field station in Cardwell, Montana. He was a geology consultant with the Amax Coal Company doing ground and surface water analysis in 1976. At the State University of New York in Fredonia, he was an instructor in geological subjects. He was also a consulting geologist for Southern Indiana Recreational Company. In 1971 as a soil science trainee with the United States Department of Agriculture-SCS, he helped map 10,000 acres in Boone County, Indiana, for a soil survey. In 1972-1973, he did research for the Department of Commerce on coastal processes and did work on dredge spoil disposal on Long Island's south shore.

He received numerous research grants and was honored by election to Sigma Gamma Epsilon, Sigma Xi, and the North Shore Task Force Karst Research Group. He also participated in the Penrose Conference on Earth Sciences and Environmental Decision Making and was a delegate from the United States to the International Speleological Congress Commission on Karst Denudation.

Dr. Ash joined the Indiana Academy of Science in 1972 and presented numerous papers on geology at our meetings. In addition to the Academy, Dr. Ash was a member of the Geological Society of America, Indiana Geologists, Indiana Speliological Survey, International Oceanographic Foundation, International Union of Speleology, National Speleological Society, and National Water Well Association. Dr. Ash published numerous papers in professional journals. His research interests included fluvial processes as applied to landscape denudation and solving engineering and environmental problems of channelization. He also studied karst hydrology as applied to ground water flow systems in response to the effects of lithologic and structural constraints. He was interested in the geomorphology of coasts, environmental interpretation of carbonate deposits and karst denudation.

Dr. Donald W. Ash was only 40 years of age when he succumbed to cancer, but his achievements were many.

HENRY S(HIRLEY) ROTHROCK

Bloomington, Indiana	Wilmington, Delaware
September 17, 1906	May 12, 1986

Dr. Henry S(hirley) Rothrock was a retired research director from DuPont de Nemours and Company when he died at home on May 12, 1986, in Wilmington, Delaware.

Dr. Rothrock was a native of Indiana, born in Bloomington on September 17, 1906. His college education began at Indiana University with an A.B. Degree received in 1926. He was a member of the tennis team there and played throughout his life. He continued his education at Purdue University where he was a chemistry assistant and received an M.S. Degree in 1928. His Ph.D. Degree was earned at Pennsylvania State University on a DuPont Fellowship in 1931. He had also studied at Columbia University in 1926 and Northwestern University in 1928 to 1929.

After graduation from the University of Pennsylvania, Dr. Rothrock joined the DuPont de Nemours Company. He was a research chemist interested primarily in organic chemistry and synthetic polymers. His work resulted in 56 United States of America patents and several publications in professional journals. In 1937, he became research supervisor with the company and in 1960, he was made liaison manager in the company's central research department. He retired in 1971. His tennis activities continued while he was at DuPont and in 1945, he won the Delaware tennis singles title and doubles title four times during the years. During World War II, he was head of the DuPont research projects commissioned by the Army and Navy. He was a member of the American Defense Preparedness Association, former director of the Philadelphia Chapter and former chairman of its national technical division on chemical warfare defense. He was awarded the Association's Bronze Medal for leadership in 1970.

After retirement from DuPont de Nemours Company, Dr. Rothrock was a volunteer consultant to the University of Delaware in the technical services division until 1980.

Dr. Rothrock joined the Indiana Academy of Science in 1926, the year he received his A.B. Degree at Indiana University. He was in Indiana for a couple of years after that while studying at Purdue University. Our society evidently made a lasting impression on him as his brother, David A. Rothrock, states, "I know he was proud and honored to be a member of the prestigious Indiana Academy of Science." His membership lasted a lifetime even though he was out-of-state. Other affiliations were the Wilmington Board of Park Commissioners, Wilmington Park and Recreation Advisory Commission, Wilmington Park Trust Fund Commission, past president of the Delaware Tennis Association, DuPont Country Club, I.U. Alumni Club at Wilmington, Phi Kappa Psi, American Chemical Society, London Chemical Society, and Armed Forces Chemical Association. In connection with his activities and participation in the development of Wilmington parks, he maintained extensive gardens. Another hobby in the years after retirement resulted in the compilation and publication of geneologies of the Rothrock and Shirley (mother's surname) families.

Dr. Henry S. Rothrock died after living a long and rewarding life of 79 years.

RALPH WAYNE STARK

Lebanon, Indiana
May 19, 1901

Lebanon, Indiana
May 26, 1984

Mr. Ralph Wayne Stark had been a business man owning the Ralph W. Stark Stationer, had worked for the "Lebanon Pioneer" (now "Reporter"), and had been Associate Editor of the "Boone County Magazine" and was a Boone County historian.

Born near Lebanon, Indiana, May 19, 1901, Mr. Stark was raised on a farm. He attended elementary school in Lebanon and graduated from Lebanon High School in 1921. He was fascinated with nature and took up college work in 1958 at Butler University where he specialized in natural history subjects such as zoology, botany and plant taxonomy. He became well-versed in wildlife, forestry, etc.

Mr. Stark lived in the Lebanon area all of his life. He owned 17 acres of wilderness just east of Lebanon which he enjoyed to the fullest. He also worked for the "Lebanon Pioneer" (now "Lebanon Reporter") until 1923. He then opened his own business, Ralph Stark, Stationer. He and his wife ran the business until 1964 when they retired.

Mr. Stark was particularly interested in the history and development of Boone County, preservation and Indian lore. Joan Lyons, feature writer of the "Boone County Magazine" and "Zionsville Sentinel," wrote a fine tribute to him in the May 31, 1984, issue of the "Sentinel". She described him as scrupulously accurate with a remarkable memory and as a person who kept voluminous records for documentation. Among his writings are "Boone County in the first hundred years", "History of Lebanon's Presbyterian Church", "Birth certificates of Lebanon and Boone County", and many magazine articles, pamphlets and booklets concerning history and conservation. He reprinted and distributed Harden and Spahr's "Early life and times in Boone County".

Mr. Stark joined the Indiana Academy of Science in 1949 and became one of our few life members. He was also a life member in the Indiana Historical Society, Indiana Audubon Society, Boone County Conservation League (which he founded in 1935) and Izaac Walton League (president of Indiana Division 1955-'57). He was a non-resident associate of the Field Museum of Natural History in Chicago. He was a member of the Chicago Academy of Science, National Academy of Sciences, Conservatory of Chicago, Wilderness Society of Chicago and National Audubon Society. He was active in politics serving as Boone County Councilman-at-large and was made Sagamore of the Wabash in 1984.

Mr. Ralph Wayne Stark died May 26, 1984, at his home at Lebanon, Indiana, at 83 years of age. He was a contributor of articles and photographs to the "Boone County Magazine" until his death.

THEODORE WILLET TORREY

Woodbine, Iowa
January 14, 1907

Bloomington, Indiana
August 31, 1986

Dr. Theodore Willett Torrey was an Indiana University Emeritus Professor and former Chairman of the Zoology Department when he died August 31, 1986 at Bloomington Hospital.

Dr. Torrey was born at Woodbine, Iowa, January 14, 1907, but his early life was spent in Colorado. He graduated from the University of Denver with an A.B. in 1927. He continued study at Harvard University where he received a Master's Degree in 1929 and a Ph.D. degree in 1932.

It was 1932 that Dr. Torrey came to Indiana University as an instructor in Zoology where he was asked to help introduce new experimental approaches to some of the living processes. He responded with a new course, Developmental Anatomy, in which embryology and anatomy were combined. During his career, he studied the nervous system, degeneration of nerves and sense organs, embryological sense organs, and embryology of the urogenital system. He was the author of a textbook, "Morphogenesis of the Vertebrates" which received wide acceptance in the United States. Dr. Torrey advanced to full professorship in 1947 and was an excellent chairman of the Zoology Department from 1948 to 1966. He retired on June 15, 1972, becoming Emeritus Professor of Zoology. He finished a 40-year record of teaching and administration at 65 years of age. At his early retirement he said, "I think I'll enjoy it. For so many years I was constantly called upon to do things other than the ones I wanted to do. Now, when the fire alarm rings, I won't have to go." (From Hugh Hazelrigg, June 7, 1972, Indiana University News Bureau release). His methods of teaching had been innovative, bringing new viewpoints and techniques to teaching such as use of visual aids including motion pictures. He was Chairman of the University Committee on Curricular Policy and Education Programs bringing changes in course and degree requirements. He also served on the College of Arts and Science Curriculum and Policy Committee involved in moving the Indiana University Junior Division to the University Division. The News Release mentioned above also stated that Dr. Torrey was known to many Indiana University graduates as "Terrible Ted", because he talked many students with failing grades into working hard and becoming successful scholars. The term was used fondly and later calls, letters or visits from grateful students were very rewarding to him.

Dr. Torrey joined the Indiana Academy of Science in 1935, so was a member for over 50 years. He was author or co-author of several papers given at the Indiana Academy of Science meetings. These often dealt with embryological subjects. He served on the Resolutions Committee in 1951 and 1952, Indiana Science Talent Search from 1952 to 1958, Special Committee for Undergraduate Research in Biology in 1957 and was mentioned by Dr. Murvel R. Garner in a history of Indiana Zoology (1967, Proc. I.A.S 76: 164-170) and Frank N. Young in a short history of Zoology at Indiana University (1983, Proc. I.A.S. 92: 297-312), both of whom had high praise for Dr. Torrey. They mentioned some historical articles written by Dr. Torrey on Zoology at Indiana University (Bios 20 (2): 67-99. 1949; unpublished supplement 1968, 21 pp.)

In addition to the Indiana Academy of Science, Dr. Torrey was a member of the American Association for the Advancement of Science, American Zoological Society Society of Experimental Biology and Medical Research, Sigma Xi, Phi Sigma, and Lamb Chi Alpha.

After retirement, Dr. Torrey had many interests. He had more time for readin and writing, gardening and photography. He was active in programs devoted to the welfar of animals and was founder of the Monroe County Humane Association and served on the board of directors for many years. Around 1972, he was appointed to the Animal Control Commission by the Bloomington, Indiana, City Council. Besides interest in biological history, he was a student of political history in the United States. He died at 79 years of age.

HAROLD E(ICHOLTZ) WOLFE

North Manchester, Indiana
June 6, 1891

Bloomington, Indiana
May 8, 1986

Dr. Harold E. Wolfe was a teacher of Mathematics at Indiana University for many years. He also received his college training there with an A.B. in 1913, A.M. in 1914 and Ph.D. in 1918. He was also a native of Indiana, born in North Manchester June 6, 1891.

After receiving his A.M. Degree, Dr. Wolfe began teaching in 1914 at the University of South Dakota as an instructor in Mathematics. He returned to Indiana University after two years to work for a Ph.D. Degree. After receiving that, he began officer's training in 1918 at Camp Zachary Taylor where he was also an instructor. He received a commission as Second Lieutenant, Artillery, O.R.C. that December. He returned to teach Mathematics at Indiana University in 1919. He was acting chairman 1953-1954 and 1955 to 1957 through some troubled times. He also conducted classes at the Indiana University Extension in Indianapolis. He retired in 1961, becoming Professor Emeritus of Mathematics. He had been highly regarded as a teacher and received Indiana University's Lieber Award for distinguished teaching in 1958. He was also a violinist, active in university circles and concertmaster of the orchestra at Indiana University. Dr. Wolfe was also active in teaching mathematics by correspondence and made contact with hundreds of students throughout the state and nation. His research field was geometry and had published a popular treatise, "Introduction to Non-Euclidian Geometry."

Dr. Wolfe joined the Indiana Academy of Science in 1920 and was a 66-year member at death. He served as chairman of the Mathematics Section in 1946 and was a member of the Executive Committee (now Council). He was also a Charter Member of the Mathematical Association of America, member of the American Mathematical Society, American Association of University Professors, Phi Beta Kappa, and Sigma Xi.

After retirement, Dr. Harold E. Wolfe appeared daily at his desk in Swain Hall to work. He was 94 years old when he died at home in Bloomington, May 8, 1986, after an exemplary life.

Indiana Academy of Science
CORPORATE MEMBERS, 1986

Ball Corporation, Muncie, IN, Dr. John Pruis
Bristol-Meyers, Evansville, IN, Rolland Eckels
Eli Lilly and Company, Indianapolis, IN, Dr. J.M. Mann
Ford Motor Company, Indianapolis, IN, Mr. H.W. Farrington
International Minerals and Chemical Corporation, Terre Haute, IN, Thomas B. Macrury
Reilly Tar and Chemical Corporation, Indianapolis, IN, Dr. Gerald L. Goe

Indiana Academy of Science
NEW MEMBERS 1986

Ackerman, Rodney R., Dept. of Biology, Ball State University, Muncie, IN 47306
Bard, Martin, Dept. of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, IN 46223
Barrett, Charles L., Indiana State Board of Health, 1330 W. Michigan St., Indianapolis, IN 46206
Bayer, Shirley A., Dept. of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, IN 46223
Beeching, Simon C., Dept. of Biology, Indiana University, Bloomington, IN 47405
Bieberich, Larry, Acres Incorporated, Decatur, IN 46733
Black, Kathryn N., Dept. of Psychology, Purdue University, West Lafayette, IN 47907
Bosin, Talmage R., Myers Hall, Indiana University, Bloomington, IN 47405
Broomall, Phillip A., Dept. of Biology, Ball State University, Muncie, IN 47306
Buckner, Richard L., Livingston University, Livingston, AL 35470
Burnett, N. Franklin, 11300 E. Stony Brook Dr., Indianapolis, IN 46229
Cantin, Mark E., Glenn A. Black Laboratory of Archaeology, Indiana University, Bloomington, IN 47405
Cervone, Thomas H., University of Southern Indiana, Evansville, IN 47712
Chapman, Albert T. Jr., 4302 S. Poplar, Marion, IN 46953
Chernoff, Ellen A.G., Indiana University-Purdue University at Indianapolis, Indianapolis, IN 46223
Clay, Keith, Dept. of Biology, Indiana University, Bloomington, IN 47405
Colon-Arroyo, David, Dept. of Biological Sciences, University of Notre Dame, Notre Dame, IN 46556
Costello, Priscilla, Terre Haute South High School, 3737 S. 7th St., Terre Haute, IN 47802
Crandall, Jack K., Dept. of Chemistry, Indiana University, Bloomington, IN 47405
Curtis, Richard K., Indiana University-Purdue University at Indianapolis, Indianapolis, IN 46202
Curtis, Stephen D., 6455 Rogers, Bloomington, IN 47401
Dhawale, Shree, Earlham College, Richmond, IN 47374
Doherty, Michael, Dept. of Chemistry, Purdue University, West Lafayette, IN 47907
Dowden, Dale, Vincennes University, Vincennes, IN 47591
Evanson, James A., Indiana University-Purdue University at Fort Wayne, Fort Wayne, IN 46805
Faus, Ignacio, Indiana University, Bloomington, IN 47401
Fereres, Alberto, Purdue University, West Lafayette, IN 47907
Franklin, Donald G., Canterbury Schools, 5601 Covington Rd., Fort Wayne, IN 46804
Gerkensmeyer, David, Perry Meridian High School, 401 W. Meridian School Rd., Indianapolis, IN 46217
Glimn-Lacy, Janice, 6810 Shadow Brook Ct., Indianapolis, IN 46224
Grant, Richard H., Dept. of Agronomy, Purdue University, West Lafayette, IN 47907
Gustin, William, Dept. of Geography and Geology, Indiana State University, Terre Haute, IN 47809
Hamm, Virginia V., Indiana State Museum, 202 N. Alabama, Indianapolis, IN 46204
Hanania, George I., Dept. of Chemistry, Indiana University, Bloomington, IN 47405
Hankins, Marie, University of Southern Indiana, Evansville, IN 47712
Hedge, Cloyce L., 60 Dean Ave., Franklin, MA 02038
Henn, Robert E., 941 University Ct., Evansville, IN 47712

Hicks, David, Manchester College, North Manchester, IN 46962
Hieftje, Gary M., Dept. of Chemistry, Indiana University, Bloomington, IN 47405
Holland, Russ, Dept. of Biology, Indiana University-Purdue University at Fort Wayne, Fort Wayne, IN 46805
Hollenbeck, Scott D., Route 6182, Delaware Dr., Vincennes, IN 47591
Hosteter, William D., Soil Conservation Service, Suite 2200, 5610 Crawfordsville Rd., Indianapolis, IN 46041
Howell, David, Box 393, Winslow, IN 47598
Hurley, Richard T., Dept. of Biology, St. Francis College, Ft. Wayne, IN 46808
Jankowski, Thomas P., Pike Central High School, Petersburg, IN 47567
Johnson, Keith, Dept. of Agronomy, Purdue University, West Lafayette, IN 47907
Kappa Kappa Kappa, Incorporated, 502 Main St., Burnettsville, IN 47926
Kelly, Martin G., Dept. of Biology, Indiana University, Bloomington, IN 47405
Kobe, Michael, Gavit High School, 1670 175th St., Hammond, IN 46324
Koska, Jane F., Dept. of Biology, Indiana University, Bloomington, IN 47405
Krauss, Cynthia J., Taylor University, Upland, IN 46989
Lafuze, Joan E., Riley Hospital, 702 Barnhill Dr., Indianapolis, IN 46223
Lampe, David, Dept. of Entomology, Purdue University, West Lafayette, IN 47907
Latin, Richard, Dept. of Botany and Plant Pathology, Purdue University, West Lafayette, IN 47907
Lichtenberg, Don B., Dept. of Physics, Indiana University, Bloomington, IN 47405
Lisby, Mark D., Muncie Center for Medical Education, Ball State University, Muncie, IN 47306
McClain, Mark S., 709 Navco Dr., Suite C, Lafayette, IN 47905
McClure, Polley A., Dept. of Biology, Indiana University, Bloomington, IN 47405
McConnell, Susan, Northside High School, 2400 Bethel, Muncie, IN 47304
McCullough, Robert, 314 S. Fairview, Bloomington, IN 47401
Manaf, Sir Mohammed Zaini, Hampstead Lodge, P.O. Box 1052, 46860 Petaling Jaya, Malaysia
Meyer, A.H., Valparaiso University, Valparaiso, IN 46383
Miller, Gary E., P.O. Box 2838, West Lafayette, IN 47906
Miller, Suzanne, Dept. of Biology, Ball State University, Muncie, IN 47306
Mocharla, Raman, Dept. of Medical Genetics, Indiana University School of Medicine at Indianapolis, Indianapolis, IN 46223
Nawrocki, Stefan, Dept. of Biology, University of Notre Dame, Notre Dame, IN 46556
Nellist, William E., Dept. of Geology, Indiana University, Bloomington, IN 47405
Njie, Mustapha Ebrima, Dept. of Entomology, Purdue University, West Lafayette, IN 47907
Osmon, Margaret, Bloomfield High School, Bloomfield, IN 47424
Pickelheimer, Bruce, 6209 Shell Dr., Fort Wayne, IN 46835
Price, Eva J., P.O. Box 6523, South Bend, IN 46660
Redmond, Brian G., Glenn A. Black Laboratory of Archaeology, 9th and Fess St., Bloomington, IN 47405
Ritter, Martha M., Dept. of Biology, Ball State University, Muncie, IN 47306
Rivera-Serrano, Ramon R., Dept. of Chemistry, Indiana University, Bloomington, IN 47405
Rolley, Robert E., Indiana Division of Fish and Wildlife, 300 W. First St., Bloomington, IN 47401
Ross, Deborah D., Dept. of Biology, Indiana University-Purdue Univesity at Fort Wayne, Fort Wayne, IN 46805
Royer, Judith A., 2259 Niewoehner Rd., Richmond, IN 47374

RUCKMAN, PEGGY, Dept. of Biology, Indiana University Northwest, Gary, IN 46408

SALARIS, STEVEN C., 626 E. Seminary St., Greencastle, IN 46135

SAZ, HOWARD J., Dept. of Biology, University of Notre Dame, Notre Dame, IN 46556

SCHAUF, CHARLES L., Dept. of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, IN 46223

SCHULTHEIS, SUSAN, R.R. 1, Box 220H, Mount Vernon, IN 47620

SCHURR, MARK R., Dept. of Anthropology, Indiana University, Bloomington, IN 47405

SIMON, THOMAS P., Large Rivers Larval Research Station, P.O. Box 727, Graylake, IL 60030

SMIETANA, MARIA, Indiana University School of Medicine, Indianapolis, IN 46223

SMITH, ALAN F., Bedford Medical Center, Bedford, IN 47421

SPEECE, SUSAN P., Dept. of Biology, Anderson College, Anderson, IN 46012

STAHL, JAMES R., Indiana Department of Environmental Management, Office of Water Management, 5500 W. Bradbury, Indianapolis, IN 46241

STEFFECK, DONALD W., U.S. Fish and Wildlife Service, 718 N. Walnut St., Bloomington, IN 47401

STEVENSON, MICHAEL R., Dept. of Psychology, Ball State University, Muncie, IN 47306

STONE, JAMES M., 410 W. Fairoaks Dr., Kouts, IN 46347

SWANSON, L.A., IMC Corporation, P.O. Box 207, Terre Haute, IN 47808

TABOR, PAUL S., Dept. of Life Sciences, Indiana State University, Terre Haute, IN 47809

TANKERSLEY, KENNETH, Glenn A. Black Laboratory of Archaeology, Bloomington, IN 47405

THROSSELL, CLARK, Dept. of Agronomy, Purdue University, West Lafayette, IN 47907

TUTUNJIAN, VATCHE, Dept. of Physics, University of Indianapolis, Indianapolis, IN 46227

TWEDDALE, JOHN B., Dept. of Geology, Indiana University, Bloomington, IN 47405

URBANO, CHARISSA, Dept. of Biology, Ball State University, Muncie, IN 47306

VANN, CAROLYN N., Dept. of Biology, Ball State University, Muncie, IN 47306

WADE, LANITA, P.O. Box #2, Greencastle, IN 46135

WALDRON, THOMAS B., Dept. of Geography and Geology, Indiana State University, Terre Haute, IN 47809

WEBER, LOUISE, Box 56, Galvin Life Science, Notre Dame, IN 46556

WEEKS, MARY V. AND W. WILLIAM, 5336 Washington Blvd., Indianapolis, IN 46220

WHITMAN, RICHARD, Dept. of Biology, Indiana University Northwest, Gary, IN 46408

WIGGINS, GARY, Chemistry Library, Indiana University, Bloomington, IN 47405

WOBBENHORST, JANICE, Indiana Dunes National Lakeshore, 1100 N. Mineral Springs Rd., Porter, IN 46304

WOERNER, JANET J., Indiana University Northwest, Gary, IN 46408

WU, DING-WEN, Dept. of Biology, University of Notre Dame, Notre Dame, IN 46556

YEAGER, RUSTY K., 1400 Russell Ave., Evansville, IN 47712

Adams Central High School Science Club, Sponsor: RICHARD ALLSPAW, 222 W. Washington St., Monroe, IN 46772

Anderson Highland High School Science Club, Sponsor: CHARLES PLUHAR, R.R. 1, Box 85, Anderson, IN 46011

Argos Community Junior High School Science Club, Sponsor: EUGENE COOPER, Argos, IN 46501

Argos High School Science Club, Sponsor: EUGENE COOPER, Argos, IN 46501

Bedford-North Lawrence High School Science Club, Sponsor: LEWIS HOLT, Bedford, IN 47421

Benton Central High School Science Club, Sponsor: MICHAEL PATCH, Oxford, IN 47971

Bloomington North High School Science Club, Sponsor: SCOTT STEPHENSON, Bloomington, IN 47401

Brebeuf High School Science Club, Sponsor: Frank Giles, Indianapolis, IN 46268
Bremen High School Science Club, Sponsor: Geoffrey Jankowski, Bremen, IN 46506
Carmel High School Science Club, Sponsor: Dennis Dijak, Carmel, IN 46032
Cass High School Science Club, Sponsor: Larry Isenburg, Walton, IN 46994
Center Grove High School Science Club, Sponsor: Judy Lines, Greenwood, IN 46142
Central Noble High School Science Club, Sponsor: Harold Sollenberger, Albion, IN 46701
Charlestown High School Science Club, Sponsor: Larry Skeens, Charlestown, IN 47111
Columbia City Joint High School Science Club, Sponsor: Sharon Gerig, Columbia City, IN 46725
Columbus East High School Science Club, Sponsor: Robert Kasting, Columbus, IN
East Noble High School Science Club, Sponsor: Virginia Rhodes, Kendallville, IN 46755
East Tipp Middle School Science Club, Sponsor: James Ballard, Lafayette, IN 47905
Elwood High School Science Club, Sponsor: Steve Patz, Elwood, IN 46036
Evansville Mater Dei High School Science Club, Sponsor: Donna Carney, Evansville, IN 47712
Evansville North High School Science Club, Sponsor: James Hollon, Evansville, IN 47711
Fort Wayne Snider High School Science Club, Sponsor: Gene Buzzard, Fort Wayne, IN 46815
Gary Wirt High School Science Club, Sponsor: David Hayes, Gary, IN 46403
Greenfield Central High School Science Club, Sponsor: Thomas Elsworth, Greenfield, IN 46140
Hagerstown High School Science Club, Sponsor: Gordon Goodnight, Hagerstown, IN 47346
Hamilton High School Science Club, Sponsor: Cynthia Brown, Hamilton, IN 46742
Hanover Central High School Science Club, Sponsor: Robert Krol, Cedar Lake, IN 46303
Heritage High School Science Club, Sponsor: John Brier, Monroeville, IN 46773
Homestead High School Science Club, Sponsor: Thomas Waning, Fort Wayne, IN 46804
Immaculate Conception Academy Science Club, Sponsor: Kathryn Langley, Oldenburg, IN 47036
Indianapolis Arsenal Technical High School Science Club, Sponsor: Carol Smith, Indianapolis, IN 46201
Indianapolis Cardinal Ritter High School Science Club, Sponsor: Greg Crum, Indianapolis, IN 46222
John Glenn High School Science Club, Sponsor: Linda Parker, Walkerton, IN 46574
Klondike Middle School Science Club, Sponsor: Lindy Heath, West Lafayette, IN 47907
Knox High School Science Club, Sponsor: Shirley Fosler, Knox, IN 46534
Lafayette Central Catholic High School Science Club, Sponsor: Patricia Mason, Lafayette, IN 47905
Lewis Cass Junior High School Science Club, Sponsor: Larry Isenburg, Walton, IN 46994
McCutcheon High School Science Club, Sponsor: Brad Montes, Lafayette, IN 47905
Milan High School Science Club Sponsor: Steven Gutzwiller, Milan, IN 47031
North Daviess High School Science Club, Sponsor: J. Merle Callahan, Elnora, IN 47529
Northridge High School Science Club, Sponsor: Gordon Noble, Middlebury, IN 46540
North Vigo High School Science Club, Sponsor: Bonita Harader, Terre Haute, IN 47804
Northwestern High School Science Club, Sponsor: L. Williford, Kokomo, IN 46901
North White High School Science Club, Sponsor: Dan Metcalf, Monon, IN 47959
Oliver P. Morton High School Science Club, Hammond, IN 46323
Park Tudor High School Science Club, Sponsor: Mark Wagner, Indianapolis, IN 46240
Perry Meridian High School Science Club, Sponsor: Gary Brendel, Indianapolis, IN 46217

Pike High School Science Club, Sponsor: Maria Walsh, Indianapolis, IN 46268
Plymouth High School Science Club, Sponsor: Donna Chaney, Plymouth, IN 46563
Princeton Community High School Science Club, Sponsor: Robert Michel, Princeton, IN 47670
Richmond High School Science Club, Sponsor: Patricia Shuck, Richmond, IN 47374
Riverton Parke High School Science Club, Sponsor: Jonathan O. Brooks, Montezuma, IN 47862
Rochester High School Science Club, Sponsor: Ralph Weissinger, Rochester, IN 46975
Seymour High School Science Club, Sponsor: Rick Schuley, Seymour, IN 47274
Shenandoah High School Science Club, Sponsor: Mary Gough, Middletown, IN 47362
South Bend Clay High School Science Club, Sponsor: Mary Sparks, South Bend, IN 46637
South Bend LaSalle High School Science Club, Sponsor: Allen Rogers, South Bend, IN 46628
South Bend Washington High School Science Club, Sponsor: Laurie Bednarek, South Bend, IN 46619
Triton Central High School Science Club, Sponsor: Charles Davies, Fairland, IN 46126
Washington Township High School Science Club, Sponsor: Gerald Adams, Valparaiso, IN 46383
West Vigo High School Science Club, Sponsor: William Fields, West Terre Haute, IN 47885
Westville High School Science Club, Sponsor: Nadine Stroud, Westville, IN 46391
Wheeler High School Science Club, Sponsor: Thomas Murphy, Valparaiso, IN 46383
Wheeler Junior High School Science Club, Sponsor: Thomas Murphy, Valparaiso, IN 46383
Whiting High School Science Club, Sponsor: LaVatta Martin, Whiting, IN 46394
Winimac High School Science Club, Sponsor: David Ralstin, Winimac, IN 46996

Indiana Science Talent Search Winners

These Indiana Science Talent Search Winners were awarded one year memberships in the Academy.

Bloom, Sally, R.R. 1, Kendallville, IN 46755
Call, Edward, R.R. 3, Albion, IN 46701
Claussen, Craig, 718 Elizabeth St., Kouts, IN 46347
Gibson, James, 2504 Derbyshire Ct., West Lafayette, IN 47906
Jansen, Douglas, 244 Burnam St., Kendallville, IN 46755
Ma, Alvina, 2608 W. Purdue, Muncie, IN 47304
Meyer, Hertha, R.R. 2, Box 329, Kendallville, IN 46755
Owens, Mark, Box 54, Michiana, New Buffalo, MI 49117
Shieh, Mae-Mae, 4912 Hawthorne Ridge, West Lafayette, IN 47906
Swain, Sheryl, 314 E. 650 N., West Lafayette, IN 47906
Tanner, Martha, 628 S. 300 W., Kokomo, IN 46902
Winicur, Zev, 1802 Dorwood Dr., South Bend, IN 46617
Wolven, Charles, 3202 43rd St., Highland, IN 46332

Ernest E. Campaigne, Professor Emeritus, Department of Chemistry, Indiana University, Bloomington.

ADDRESSES AND CONTRIBUTED PAPERS

PRESIDENTIAL ADDRESS

"Quo Vadis or If Nobody Does Anything, Nothing Will Be Done"

Ernest E. Campaigne
Department of Chemistry
Indiana University
Bloomington, IN 47405

This year I have spent a great deal of time thinking about the nature and purposes of the Indiana Academy of Science. In 1986 the Academy entered its second 100 years. When you are 101 years old, you are entitled to a little introspection. Why are we here? Are we doing what we should be doing? Can we improve?

The Indiana Academy of Science is the primary membership society in the state of Indiana for all qualified individuals whose major professional concerns involve significant aspects of the sciences. The mission of the IAS is to provide leadership and support for the continuous evolution and applications of the sciences; for the professional growth and well-being of scientists; for the development of appropriate appreciation by the public of the contributions to human welfare by science and scientists; and to provide a wide variety of high quality communications and other services to members, the state legislature and other state entities, and to the public, for the benefit of all the citizens of Indiana.

These last two points find strong support in recent quotes. From "The Public Understanding of Science," a report by the Royal Society, London, 1985, we learn:

"Science and technology pervade nearly all aspects of modern life, from the health of individuals to national prosperity to the quality of public decision-making. Improving public understanding of science is not a luxury, it is a vital investment in the future well-being of our society. Initial responsibility for achieving an improved public understanding lies with the scientific community. Learn to communicate with the public, be willing to do so and consider it your duty to do so."

The president of M.I.T., Dr. Paul E. Gray, addressing the A.A.A.S. meeting in Philadelphia in May, 1986, said "Every individual who is involved in and cares about these issues has to be involved in making the case for higher education and the research enterprise. We, as scientists, cannot assume that good works will be supported simply because they are good works. And we cannot stand aside and expect others to make the case for us. We must become involved in the decision-making processes and in communicating the value of what we do."

The expanding base of scientific knowledge must be made readily accessible to provide information that will support solutions to problems of society. Therefore, the Indiana Academy of Science should strive to enlarge its role in the transfer of knowledge. Information services, including further monographs and the *Proceedings*, and meetings and symposia, should be sustained and increased in scope and relevance to the needs of those they serve.

Some wise man said, "As we learn, questions, not answers, become the focus of our attention."

Let me raise some questions about our role in the transfer of knowledge.

Should the *Proceedings* of the IAS be modified? The length of current volumes is a problem for the editor and the printer, and an added expense to the Academy. Quarterly research journals are published by science academies in neighboring states. Should we attempt a quarterly research journal?

This year for the first time, we have distributed abstracts at the meeting. Should we continue this practice? Publication of meeting abstracts separate from the *Proceedings* has several distinct advantages. It would:

a) Reduce the size of the *Proceedings* by about 10%.

b) Provide an early publication date. At present, the actual publication date is 12 to 15 months after a paper is presented. Publication of abstracts at the meeting would give the meeting date as publication date.

c) Provide an opportunity to review abstracts of papers before attending, making it easier to select important papers.

d) Provide information for discussion of papers you have missed with the author.

There are some disadvantages also:

a) Abstracts are not edited, so authors have sole responsibility for appearance.

b) The published abstracts would have to be distributed to our membership and library exchange list as a regular publication of the Academy, at extra expense.

Should the *Newsletter* be published more often? The Academy needs more contact with its members. It seems to have a major impact just once a year, at the annual fall meeting. The *Newsletter*, published four times/year, has been greatly improved under the editorship of Al Schmidt. He has introduced a new two-column format and made it more readable, and has introduced some new features, "Letters to the Editor," "President's Corner" and "Know Your Committee," to name a few. It could be used by sections, which seem to lack communication with their members, except for the annual invitation to submit. It could be used by committee chairs seeking input on their missions. Is a monthly news magazine possible? Maybe we should ask the editor to try for six times/year, on an experimental basis. Please give him the benefit of your advice.

Can our meetings be improved? It is getting more and more difficult to squeeze in all of the events and papers into one day (but most attendees will not stay overnight). The Council meeting on Thursday is poorly attended, and seems only to be able to meet in the afternoon for two hours. How can we better conduct the business of the Academy? Shall we have papers at the spring meeting? Can we have some symposia at other times of the year? Can we get cooperation between sections to arrange such symposia? Perhaps the proceedings of such symposia could be published as monographs.

It is becoming more difficult to have meetings on college campuses. Institutions are not clamoring to host the Academy. How can we meet this problem?

a) Meet at a different time, when more space is available on campus. Christmas and Easter vacations are getting longer, and there is usually space available during summer vacations.

b) Meet in hotel facilities. This would be very expensive, since all facilities would cost. Our registration fee currently does not pay the cost of a meeting. In 1985, the meeting income was about $4000, but the meeting, held at Indiana University in Bloomington, cost about $7000. Thus even with a modest registration fee, the Academy is subsidizing about one-half the cost.

How can we increase our membership? There are more than 2000 practicing professional scientists in the state, but we have only about 1000 members. We have only 5 or 6 corporate members, but there are many times that number of corporations with vested interest in science in this state. Increasing our membership in all categories will enable the Academy to provide better services.

How can the corporate member take an active part in Academy affairs?

a) They can promote understanding and appreciation of the contributions of industrial scientists to society and the economy of the state.

b) Corporate members can provide seed money and support for selected Academy programs.

c) They can function as a communication link between corporations, the Academy and the state.

Why can't the various sections of the Academy become more involved in Academy projects? For example, why doesn't Science Education get more involved with Youth Activities' problems, the review of high school texts, the Indiana State Museum, and so on. It seems to me that our sections are completely divorced from Academy committees, where the action is.

Can we get more cooperation between sections on arranging symposia? Some obvious ideas come to mind. Chemistry and Environmental Quality could sponsor a joint symposium on methods of measuring trace materials in air, water and soil. Soil and Atmospheric Science would surely cooperate, or perhaps prefer to arrange a symposium with Ecology. Certainly Botany, the Biologies and Zoology must have mutual interests. It seems to me that joint symposia of this kind would attract much broader general interest.

Can we do more in the field of science education? Recently, Norman Hackerman, on receiving the Parsons Award of the American Chemical Society, said, "The country is losing its potential scientific talent to law, medicine and finance these days. I don't think we scientists are getting a good look at the intellectually high class kids." (Chemical and Engineering News, June 23, 1986, p. 27). Our Youth Activities Committee is one of the most important committees of the Academy. They are doing a good job under difficult circumstances. They are responsible for the Junior Academy, the Indiana Science Talent Search, Science Fairs, the Science Olympiad, and, in cooperation with the Research Grants Committee, high school student research grants. And they do all this with minimal financial backing by the Academy. If they are to keep up the good work, they need more help and more money. Can the Academy do more? We need to promote a membership drive among the high school science teachers, and offer them more services of the Academy. We need to explore greater cooperation between IAS and HASTI, and improve our work with the Indiana Science Education Fund. Furthermore, we need to call to the attention of the corporate members the work of the Youth Activities Committee. I see here a natural affinity. Can the Academy nurture it?

Recently the Delaware General Assembly established a "Scientist in Residence" program in the Delaware elementary schools, to strengthen the teaching of mathematics and science in the public schools. Scientists in Residence will cooperate with elementary school teachers in developing science lessons emphasizing observation and experimentation. This idea was developed by a group of retired chemists in Delaware. Could the Academy develop such a program for the state of Indiana, utilizing the talents of retired Academy members? A description of this program can be found in Chemical and Engineering News, May 12, 1986, p. 27.

The Academy needs a headquarters office, centrally located, preferably in Indianapolis, near state government offices. Such an office can provide continuity to various ongoing operations and provide office help which is sorely needed. An increasing load is falling on fewer volunteer shoulders, and it becomes more difficult to meet deadlines. Our Academy is ninth largest in the country, but not among the 26 which list a central office, nor among the 21 which list an Executive Secretary. Such an office can handle routine mailing and billing, maintain a computerized up-to-date membership list, assist various committees in contacting the membership of the state, negotiate for meeting sites, prepare programs and abstracts, negotiate contracts for printing and publication, provide a permanent address and phone for Academy business, and more.

To sum up, the Indiana Academy of Science should expand its efforts to communicate with the public, maintain and expand an aggressive program to provide accurate, relevant scientific information on public issues involving science to all appropriate agencies of state government; assert leadership in encouraging public and private institutions to act responsibly using available scientific and technological information in matters of public concern; and improve its interactions with the communications media. In all these efforts, it is vital that the Academy maintain its credibility as a voice for science and the scientists.

The fullest realization of the objectives of the Academy depends on astute management of its assets and of the financial aspects of the endeavors undertaken in accord with these objectives. The IAS should manage its activities to meet their service objectives and to generate sufficient funds to meet its future capital needs. IAS should seek private and public support to achieve specific well-defined Academy goals with carefully developed strategies. Dues-supported programs should be managed so that member dues remain at a reasonable level.

In conclusion, I would like to take this opportunity to thank the chairs and members of the many committees who have worked hard this year to improve their service to the Academy. I am especially grateful to Virginia Rhodes, Mark Whitman and Janet Woerner, who stepped in to assist Susan Johnson in the operation of the Youth Activities programs. I want to thank also the Executive Committee, Stan Burden, Duvall Jones, Dick Conklin, Al Schmidt, Ben Moulton, and last but not least, Don Winslow, my good right arm, who knows where all the bodies are buried, and without whose counsel and support I would have been unable to preside. I wish your incoming president, Stanley Burden, the best of luck. Thank you.

"SPEAKER OF THE YEAR" ADDRESS—1986-87

"Science and National Security Policy"

Ruth H. Howes
Department of Physics and Astronomy
Ball State University
Muncie, IN 47306

Introduction

Scientists are not politicians and most politicians are certainly not scientists. Nevertheless, scientists and politicians alike agree that science affects the making of national security policy. The influence of scientists on policy making depends on the technical issues and the personalities involved. Today I will examine the theory and practice of the bureaucratic mechanisms by which high level policy makers obtain, evaluate and use scientific information in formulating national security policy.

Scientists outside of government generally see the role of science in policy as telling policy makers whether a technical project can or can't be done. In principle, the President and the National Security Council have access to the best scientific brains in the nation through the office of the Science Advisor to the President, who as of October this year, is William R. Graham. Graham is a 48 year old electrical engineer who holds a Ph.D. from Stanford and has had a career in defense research with RAND and R&D Associates. He was appointed second in command at NASA two weeks before administrator James Beggs resigned to defend himself against charges of criminal fraud. Thus, Graham found himself in charge of NASA six weeks later when the Challenger shuttle exploded. Although Graham was a newcomer to the space program, he responded to Congressional investigations of the disaster. Under normal circumstances, Graham would probably have been named administrator of NASA, but the administration decided that it needed a better known administrator and named James Fletcher to the job. On June 3, Graham was nominated to the post of presidential Science Advisor and Director of the Office of Science and Technology Policy which had been vacant since George Keyworth resigned in January. Because the White House delayed sending the nomination to the Senate, Graham was confirmed only last month. At the same time, the budget of the White House Office of Science and Technology Policy was cut to $1.6 million from $2.2 million. Recent events indicate that the Reagan administration's top advisors consider the input of this office of less than critical importance.

Each of the major cabinet officers also commands a bureaucracy in which are embedded many scientists. There are reservoirs of scientific expertise in the national laboratories, the defense contractors and the universities all of which may be consulted. Thus in principle, there is no dearth of scientific advice available to the men who run the country. Unfortunately the process of transferring technical information to the men in power is not by any means as simple as it seems on paper.

There are several reasons why scientific information does not fit easily into policy decisions. First, the better the scientist is, the more reluctant he (or she) is to express an absolute opinion. We are all trained from freshman labs on up to express our results with carefully calculated error bars. Politicians want black and white, simple answers that are anathema to scientists. For example, a policy maker might ask a science advisor whether or not the Soviets have violated the provisions of the unratified SALT II treaty by developing the SS-25 missile or whether the missile is a follow-on to the SS-13 which would be allowed by the treaty. The argument hinges on the precise definition of throw-weight of a missile and our ability to measure it to an accuracy of 5%. Few top level policy makers have the time, the technical background or the inclination to understand the details of the argument. Thus they take the word of their advisors and conclude that: "Testing and deployment of this missile violates a central provision of the SALT II treaty. . ."(1). Public information and Congressional debate are all too often limited to blunt statements that mask the technical issues involved.

Secondly, scientists may bias their results by their political opinions. The mistakes may reflect honest errors but studies have shown that results, in studies of ESP for example, follow the bias of the experimenter. Why should the situation be different in the national security policy arena? If the scientists themselves produce solid data, the data may be distorted by analysts up the policy ladder who simplify the raw scientific data so that the political policy makers can understand it in a relatively short period of time. It is axiomatic in Washington that the higher the rank of an administrator, the less time he will have available to understand the very important issues which he is judging. It is also possible that Machiavellian figures in the chain of command may deliberately distort data for their own political ends. Lastly, in the arena of national security policy, the classification of data and analysis may be so strict that lower level analysts who write the papers which reach policy makers may not even be aware of the facts.

The Making of National Security Policy in the Reagan Administration

The President of the United States has absolute control of U.S. national security policy, subject only to the advice and consent of the Senate and, of course, the budgetary control of Congress. The word of the President or his personal spokespersons is the voice of the United States in establishing foreign policy. As one senior bureaucrat put it, the littlest minnow on the White House staff overrides whales elsewhere in the national security bureaucracy. Any member of the executive branch bureaucracy must speak publicly in accord with policy set by the White House. Otherwise it would be impossible for friends or foes alike to know where the U.S. stands. It is difficult for academic scientists to get used to keep ing such a careful watch upon their opinionated tongues.

Next to the President himself, the highest decision making body for formulating U.S. policy is the National Security Council (NSC). The National Security Council chair, Vice Admiral John Poindexter, served the former chair, Robert MacFarlane, as principal deputy. He is known as a team player who shuns the press and feels his job should be low profile. Rumors abound that he obtained his present position when White House Chief of Staff, Donald Regan, grew jealous of MacFarlane's influence on foriegn policy issues. Certainly Poindexter has seemed less able to control feuding factions within the NSC than MacFarlane. The offices of the National Security Council are in the Old Executive Office Building which is territory within the temple of power in Washington. Its chairman traditionally has private access to the President. The staff of the National Security Council is directly controlled from the White House. There is a very high turn over rate because people typically work seventeen hour days, seven days a week under the worst sort of pressure, simultaneously handling several different crises. The staff varies in quality from experienced experts of unquestionable ability to political appointees who lack experience, knowledge and, arguably in at least one case, intelligence. Needless to say, all the staff reflect the views of the President in that they are conservative in international affairs and tend to profoundly distrust the Soviets.

In addition to Admiral Poindexter, the National Security Council has three full members. Secretary of State George Shultz had no background in strategic policy or arms control issues when he was appointed. Shultz's principal advisor is Paul Nitze who holds the title of Special Advisor to the President on Arms Control. Nitze has been actively involved in arms control negotiations and national security affairs since World War II. He probably understands the Soviets and the negotiating process better than any one else whose name will be mentioned here. He is respected by all political factions in this country and by the Soviets and the allies abroad. Personally he is eighty years old, white-haired, slender and very patrician. He made his fortune from scratch before he entered public service. He married a wealthy wife, rumor has it, for love and reportedly earned his first million to be worthy of her. He is highly intelligent, incisive and very, very shrewd. Nitze is not a scientist but has a thorough grasp of the technology of nuclear weapons.

The Department of Defense is represented by Secretary of Defense Caspar Weinberger who also had no previous experience in strategic policy. His principal deput is Undersecretary of Defense for Policy, Fred Charles Ikle. Ikle has served as director of the U.S. Arms Control and Disarmament Agency and has a long track record of working with strategic issues. Recently he has maintained a very low profile in public and in the interagency process. The public personage in the business of making policy in the Office of the Secretary of Defense is Assistant Secretary of Defense for International Security Policy, Richard Perle, who serves as Ikle's deputy. Perle worked for many years for Scoop Jackson as the Senator's aide on foreign policy. He influences American strategic policy to an extent that is out of proportion to his relatively low rank. He is a master of bureaucratic infighting and knows every trick in the book. (He has even written a few new chapters over the last several years.) Perle is an articulate spokesman for the policies of the far right and has a profound distrust of the Soviets to the extent that he openly advocates discontinuing the arms control process. He does not sit on the National Security Council but often represents Weinberger at the next level down in the interagency process. He treats Congressional committees like graduate students and they love him.

The last, least publicized, member of the Council is William Casey, the Director of Central Intelligence. Casey heads the CIA directly and the entire intelligence establishment indirectly. He follows the pattern of his agency in not seeking, or even actively shunning, personal publicity. He is a friend and long-time advisor to Reagan. The control of intelligence data gives him enormous power in the interagency process. All policy decisions must be based on data provided by the intelligence community. The power of the man who can sway assessment of raw intelligence data and control the way it's presented to the rest of the policy makers is enormous. Besides the CIA, there are two other major intelligence agencies, the National Security Agency and the Defense Intelligence Agency, as well as the independent intelligence groups run by each of the services and the "foreign technology specialists" in the national labs. Various agencies have their own special areas of expertise. For example, buried within the Air Force's intelligence apparatus are two or three men who specialize in the Chinese missile program. Most of the time they have little work to do and are ignored by the rest of the intelligence community. On the days when the Chinese fire off a test, they suddenly become critical members of the staff and enjoy a week of frantic work and major importance. If a crisis suddenly erupts in a little studied area of the world or with a weapon nobody has studied for a while, there can be scrambles within the community to dig up somebody who at least has an idea of what is going on. When Iraq used mustard gas to attack Iran, the intelligence bureaucracy struggled to locate the men who remembered our concern with it during World War II.

The CIA leads the intelligence community. The well-publicized covert operations are actually one of its relatively minor functions. Most of the people who work in its huge office building engage in analysis of intelligence gleaned from quite open sources. For example Russian majors spend their time reading and summarizing Soviet agricultural reports in an effort to predict crop yields. The intelligence community, call it the IC for short, packages its information in National Intelligence Estimates, NIEs, or Special NIEs, SNIE's obviously, which are argued out by committees within the intelligence community. The different agencies frequently disagree in their interpretation of existing data and arguments in committee over whether a Soviet action "almost certainly constitutes," "probably constitutes" or simply "might constitute" a treaty violation grow loud, long and bitter. Occasionally a document appears like a recent description of Soviet theft of U.S. technology which is not from the IC and has no listed author or official source although you can get it from the Office of the Secretary of Defense. Such documents should be distrusted since they have clearly not received approval of the government as a whole. They usually represent the attempt of one political faction to force its interpretation on policy makers. A similar example was the well-publicized report on Soviet treaty violations produced by the General Advisory Committee to the Arms Control and Disarmament Agency in which Soviet violations were listed uncritically without benefit of argument withn the community of intelligence experts.

In addition to Poindexter, Shultz, Weinberger and Casey, there are two advisors to the NSC, the chairman of the Joint Chiefs of Staff and the director of the Arms Control and Disarmament Agency. During this administration, neither has played a leading role in shaping arms control policy. The Chairman of the Joint Chiefs, Admiral William J. Crowe, Jr., represents the uniformed, professional military. His point of view is distinct from that of the politically appointed civilians in the Office of the Secretary of Defense. In this administration, the Joint Chiefs have often supported the State Department position on policy issues. Admiral Crowe is a submariner and thus unusual for top navy brass who are usually aviators or commanders of large surface ships. The Arms Control and Disarmament Agency is represented by Ken Adelman who is under forty years old and very young for his post. Before his appointment, he worked at the United Nations with Jean Kirkpatrick. His expertise was in African affairs. In this administration, he generally has agreed with Weinberger on policy issues. Adelman is not close to Shultz which is probably unfortunate since traditionally the director of his agency has worked closely with the Secretary of State.

National policy is made when one of the members of the National Security Council decides that we need a policy on a certain issue. One of the cabinet members or advisors or the President himself may desire a look at a particular policy. Congress may demand policy as it did on the question of Soviet compliance with existing arms control treaties. Outside events may force us to develop a policy as Iraqu's use of chemical weapons against Iran forced a new look at our policies for the prevention of the proliferation of chemical weapons. On very rare occasions, a good idea from within the bureaucracy may surface in the form of a paper presented by one of the members of the NSC who is often interested by his staff or the NSC staff.

Once the National Security Council has decided to make policy, the job of looking at options is tasked to an interagency group (IG), the best known of which is SACPG—the Senior Arms Control Policy Group or "sack pig." (It can't lose the pronunciation although the I for Interagency which used to sit between Policy and Group has been officially deleted.) Deputy heads of agencies staff the IGs. The interagency group forms a lower level group, the interagency working group, where different aspects of the policy issue at hand are assigned to the appropriate agency. Representatives at this level are bureau heads with expertise in the particular area that is needed. For example, a working group on anti-satellite weapons issues would include representatives from the Office of the Secretary of Defense, the Air Force, the Strategic Programs Bureau and the Verification and Intelligence Bureau of the Arms Control and Disarmament Agency, the State Department, the CIA, the DIA, the NSA, NASA, the Department of Energy and possibly other agencies like the Department of Commerce if it seemed the new policy could affect them. Each agency member of the working group in turn assigns the problem to a bureau which assigns the task to an individual on its staff. The staffer, who may or may not have expertise in the issue at hand, writes an initial paper that is much like a term paper in form except that it contains no references. If you cite your sources in this game, you lose them. The papers then travel back up the bureaucratic highway to the National Security Council and reach the President in the form of one or at most two page decision papers with a box to check to select the policy option he wishes and a place for him to sign. Most of the science is fed into the process at the level of the original papers prepared by the staffer who may or may not call up friends in his own or other agencies who have technical backgrounds. Personalities play a formative role as the policy climbs the ladder in the intense verbal wars in the interagency process.

There are real differences between working in a classified environment and the university. In a classified situation, you can't do a literature search. The higher the level of classification involved, the more information is stored in the heads and safes of a very few workers in the field who may or may not share it with others. Thus one often wastes time reinventing the wheel. Furthermore, experts often work for the defense contractors, the national labs, and the universities. Contracts are monitored by relatively junior military officers or bureaucrats who are honest, intelligent and well-educated but not experts in all the fields where there are contracts or there would be no need to let contracts in the first place. Any scientist worth his salt is at least half way a salesman. Certainly he can convince anyone not expert in the field that his results are correct. Open literature journals and the National Science Foundation handle this by a peer review system which does not exist in the classified community. Therefore classified technical work ranges from the very excellent to the extremely shoddy and is all taken with equal seriousness in spite of the best efforts of contract monitors. Add to this the fact that results may be suppressed for political reasons as they climb through the interagency process and it become apparent that the very best technical information is not reaching decision makers. In a classic historical case, some of the warnings of Pearl Harbor did not reach men who would have been able to correlate them with other data because lower level technical workers who did not know the other data decided they were not important enough to worry their superiors.

An Example: Nuclear Test Bans

Having examined the political mechanisms for making national security policy, it is instructive to look at a case where science and national security policy overlap. You will have to decide whether the interference should be termed constructive or destructive.

The basic idea of a nuclear test ban is that new delivery systems such as larger, higher acceleration ICBMs generally require newly designed warheads. If for example, the Soviets decided to deploy the maximum possible number of warheads on their large SS-18 missile, this would greatly increase the numbers of hard targets they could strike inside the United States. To maximize the carrying capability of the missile, the Soviets would probably design a new model warhead with the yield, weight and geometry best suited to the SS-18 in this configuration. Before any weapons designer would guarantee his work, he would wish to test it. Thus if no nuclear warhead could be tested, no new designs of warheads could be deployed and this should slow down the increase in sophistication of the delivery systems found in the arsenals of the superpowers. It seems, at first glance, to be a simple idea and a very practical one. Unfortunately a second look reveals several levels of political and technological complexity.

To begin with, various test bans have been the subject of one ratified treaty, two signed but not ratified treaties and one much-discussed treaty that has never been completely negotiated. The Limited Test Ban Treaty (LTBT) forbids nuclear testing except underground. It was signed in 1963 when the world suddenly woke up to the increasing background radiation from nuclear weapons testing by the U.S. and the USSR with help from France and the U.K. Alarming reports of Strontium 90 in milk in New Jersey circulated in this country and the pressure from non-nuclear powers to ban testing in the atmosphere increased rapidly. The road to the treaty was not a smooth one, but since its ratification, it has been observed by all nations who have signed it. Even France, which has not signed the treaty, now tests underground. All nations have occasional venting from unexpectedly large tests or poorly buried explosions. The charges leveled against the Soviet Union by the U.S. refer to debris from venting which was traced beyond the borders of the USSR. Intelligence sources probably eagerly sampled the debris since it is possible to learn much about the construction of a nuclear weapon from the radioactive debris it releases. We could tell whether a Chinese test was triggered by uranium or plutonium fission from the debris we collected on the roof of Cooper Science Complex in Muncie.

In 1974, the Threshold Test Ban Treaty (TTBT) was signed. It limited nuclear tests to a maximum of 150 kilotons in designated test sites. If it had been ratified, the signatories would have exchanged geological data on the test sites and set off calibration explosions so that each could have confidence in its ability to measure the yields of the other's tests by seismic methods. In 1976, the Peaceful Nuclear Explosions Treaty (PNET) was signed by which signatories reserved the right to detonate nuclear devices for peaceful purposes outside of designated test areas both in their own territory and the territory of third parties. Individual explosions were limited in magnitude to 150 kilotons so the peaceful explosions could not be used to covertly test large warheads. Detonations were to be announced in advance and extensive geological information and technical details on depth of the shot etc. exchanged. Observers were to be allowed limited access to the site after the detonation to make measurements, making this the first treaty among the nuclear weapons states allowing any form of on-site inspection.

In one of the great mistakes of arms control, the Carter administration failed to press for ratification of these two treaties because they felt that they were very close to agreement on negotiation of the Comprehensive Test Ban Treaty (CTBT) which would ban all nuclear testing. In the event, the negotiations for the CTBT collapsed and have been broken off under the Reagan administration. The TTBT and the PNET are observed in principle by both superpowers but the exchanges of data and observers which would have increased our ability to monitor the treaties have not taken place. The Soviet Union has recently sought to re-open negotiations on the CTBT and has observed a unilateral moritorium on nuclear testing since August 6, 1985 which it keeps extending despite U.S. refusal to match it. On February 26, 1986, the U.S. House of Representatives passed a resolution calling for immediate ratification of the TTBT and the PNET and resumption of talks on the CTBT.

There are two basic technical issues which impact the test ban treaties. First is the question of whether national security requires at least a limited number of nuclear tests. It is argued that it is necessary to test in order to insure the reliability of our nuclear stockpile. The critical part of a modern warhead is the fission trigger which starts the fusion explosion. Most experts agree that it is a sufficient test of the warhead if the fission trigger ignites and starts the fusion explosion. Therefore it is possible to test warheads adequately at a fraction of their full yield. Since the yields of the largest modern warheads (not counting the Titan missiles which carried 9 megaton warheads and have posed more danger to Arkansas than the Ukraine for several years now!) are on the order of 500 kilotons, tests at 150 kilotons are adequate to ascertain that they work. Proponents of a comprehensive test ban argue that no flaw in a warhead has ever been uncovered thorugh testing although several have been discovered by inspection. Warheads have a finite shelf life established by factors such as the decay of the tritium initiator used to start rapid fission or chemical deterioration of their conventional explosives. They must be overhauled every few years and can be inspected then. If the Soviet's relatively simple weapons give them an advantage in reliability, then our designers had better get busy and reduce the complexity of their designs.

Proponents of testing point out that we need to modernize our arsenal and must test to do so. This is the effect that opponents of testing wish to stop by the test bans so the technology here is not in question. At a more subtle level, proponents point out that testing will assist in making weapons safer to handle and less likely to detonate by accident. Opponents merely add that the safest nuclear warhead is one which has been dismantled. It should be added that the most ardent testing advocates agree that it is highly unlikely that a warhead would undergo nuclear detonation by accident. It's not all that easy to set off a fission explosion! The danger is that the conventional explosive in the warhead will detonate and scatter plutonium around the countryside making a terrible mess which is expensive to cleanup and not very healthy for local residents.

Finally, advocates of testing state that we need to test in order to avoid technological surprise from the Soviets both in warhead design and in the effects of nuclear blasts on our military hardware. Rumor has it that British and American experts met shortly after the signing of the LTBT. They were discussing the effects of nuclear detonations and the Brits remarked that just as the ban went into effect they were bringing a truckload of soil from London to their test site to see what it would do under the influence of nuclear radiation. The Americans laughed and pointed out that their truckload of soil from Washington had been caught midcontinent by the ban. Advocates add that testing will improve our fundamental knowledge of the physics of nuclear explosives and provide a cadre of experienced scientists who understand the design and construction of nuclear weapons. They imply that no designer worth his salt will stay in the field if he is not allowed to verify his designs by testing. Test ban supporters point out that the Soviets will not be allowed to test either and that surely our computer systems for design and modeling of nuclear explosives are at least as good as theirs. Bomb designers could profitably get to work on more efficient engines for automobiles or any of the interesting and practical engineering problems which exist.

Peaceful nuclear explosions have proved to be of little practical use. We tried to use them to dig harbors and to create a cavity into which natural gas would seep for pumping to the surface. The harbor could have been excavated more cheaply using conventional explosives and the gas was too radioactive to burn so we do not currently use nuclear explosives for any peaceful purpose. The Soviests do use nuclear explosions as seismic sources in prospecting for oil reserves.

Until very recently, most experts agreed that testing at yields below 150 kilotons was adequate. The invention of the x-ray laser which is Edward Teller's favorite Strategic Defense Initiative weapon has changed this assumption. X-ray lasers radiate at very short wavelengths and so do great damage to targets in a very short time. The x-ray laser pumps atoms into excited states using the radiation from a nuclear explosion. The excited atoms emit characteristic x-rays in laser action before they are destroyed by the blast wave of the explosion. It is not altogether certain that the weapon actually works as well as its builders at Lawrence-Livermore National Laboratory have claimed. Even if it does work, its military significance is open to question. What is certain is that a militarily useful model will have to be pumped by a nuclear device whose yield is on the order of megatons. Some enthusiasts advocate scrapping our agreement to abide by the unratified TTBT. Incidentally, tests of a working model of the x-ray laser will have to be conducted above the atmosphere and will therefore violate the LTBT. Nuclear tests with yields of a megaton cannot be conducted at the Nevada Test Site since their shock waves would damage buildings in Las Vegas.

The second technical question concerning test ban treaties is whether we can adequately verify Soviet compliance with them. We feel reasonably confident that we can at least monitor the LTBT with great accuracy for sites in the Soviet Union. Unexplained events, like the mysterious flash of light in the South Atlantic in 1979 which triggered our nuclear detection satellites, will be better monitored by a new detection system that is being deployed on the satellites of the Global Positioning System. Most experts are comforable with our ability to monitor that treaty using satellites or by detecting radioactive debris from tests conducted in the atmosphere.

The primary method of monitoring the TTBT or the CTBT uses global networks of seismic stations. When a nuclear explosive is detonated, it sends seismic waves thorugh the earth which are picked up by seismic stations at very great distances from the detonation. There are two basic types of seismic waves which travel by different mechanisms. S waves are side to side or shear waves and P waves are essentially compression waves. Nuclear explosions produce more pressure waves than an earthquake of similar size. By comparing the relative magnitude of P and S waves, it is possible to discriminate against earthquakes. Other factors which help to distinguish nuclear explosions from quakes are that earthquakes are usually much deeper than explosions and that the Soviets generally test only in sites set aside for the purpose.

For nuclear explosions on the order of 100 kilotons, it is virtually certain that seismic stations will tell us that a detonation has taken place. The question is considerably trickier for much smaller nuclear blasts. Most seismologists agree that we can probably detect tests down to 10 kilotons. Many argue that we can see smaller explosions but the issue of detection of blasts below 1 kiloton is open to legitimate technical questions. For example, a determined cheater might wait to set off a blast until an earthquake occurs in a convenient location and hide the nuclear blast in the siesmic signal from the quake. It is hard to imagine the test crews waiting patiently for such an opportunity when they are under pressure to get results. Communications will have to be excellent and crews at the knife-edge of readiness to get the shot off in time for its seismic signals to blend into the earthquake signals. A more realistic scenario involves exploding the device to be tested inside a large cavity to decouple the blast from the earth and reduce the seismic signals produced. This will be expensive since the cavity will have to be extremely large. High frequency seismic signals are transmitted to cavity walls far better than the lower frequency signals traditionally used for monitoring testing. New seismographs work at higher frequencies and negate much of the advantage of the cavity scheme for hiding tests. Below 1 kiloton, there can be a variety of conventional explosions of comparable yield. Therefore even if a blast is detected, it could be a test of a conventional explosive. The question thus becomes whether there is any military utility in testing nuclear explosives with yields on the order of tons. In order to protect their own troops, most field commanders would rather use conventional weapons than nuclear weapons so there is no market for extremely small tactical nuclear explosives. The fission triggers on strategic and larger tactical nuclear weapons must be considerably larger so it seems that tests below one kiloton have very little military value anyway.

A second verification problem concerns methods for measuring the yield of a nuclear detonation which again is done from a seismic signal. The yields of our own nuclear tests were plotted against the magnitude of their seismic signals. The logarithm of the yield increases linearly as a function of the seismic magnitude. A good fit was obtained for data from the Nevada Test Site. When the French gave us yields for their tests in the Sahara, it became obvious that a correction factor, called the bias, had to be subtracted from the seismic magnitude to bring it into agreement with the Nevada data. The slope of the line for the two sites stayed the same but its intercept changed. This happens since the geology of the sites is very different not only on the surface but deep in the crust. The same thing happens at the Soviet test sites.

The magnitude of the bias that is appropriate for the Soviet site has become a politically critical issue. The Reagan administration has charged that the Soviets have systematically violated the TTBT by exploding nuclear devices with yields greater than the allowed 150 kilotons. Their charges are based on yields of Soviet tests computed using a value of the bias set officially some years ago. Most seismologists, including many working for the Department of Defense and certainly those in the national labs, feel that the official value of the bias is too low. Panel after panel of experts has recommended raising the bias for the Soviet site. Because the relation of yield to seismic magitude is logarithmic, theses changes are sufficient to change the calculations of the yields of Soviet tests to show that the Soviets have observed the TTBT very well indeed. Obviously these reports are a politically hot potato. They have not been released although according to Science Magazine, the CIA has urged their release. The feud has been conducted between Weinberger and Casey themselves. Lower level technicians have ducked or been crushed in the war because as the saying goes, "When the elephants dance, the mice had better run unless they have an elephant for a partner!"

In April, 1986, Casey formally ordered a change in the numerical methods used to estimate Soviet yields which reduced their estimated values. Because the yield increases logarithmicly with the seismic magnitude, large uncertainties in yield result from small uncertainties in measuring seismic magnitude so a Soviet test whose measured yield is 150 kilotons may statistically have an actual yield as low as 75 kilotons or as high as 300 kilotons. In other words, there is a factor of two uncertainty in the measurement of the yields of Soviet tests. Yield estimates improve as seismic networks are placed closer to the test site and its geology is better understood. The yields of U.S. nuclear tests are measured by sampling the radioactive debris emitted by the explosion and are believed to be accurate to about 10%.

The Soviets have recently allowed a team of seismologists from the private Natural Resources Defense Council to tour their test sites and to establish three seismic stations in the Soviet Union. A major paper by Evernden, Archambeau and Cranswick published in the May issue of Reviews of Geophysics argues that a network of 25 high frequency monitoring stations established within the Soviet Union could monitor tests with yields down to one kiloton with an extremely high degree of confidence. Soviet seismologists working with the Natural Resources Defense Council will establish three seismic stations in this country but have not been allowed to visit the Nevada Test Site nor have they received an official belssing from the government.

The Reagan administration holds that seismic methods are not adequate for verifying the TTBT. It will consider ratifying the treaty if the Soviets will agree to the use of the CORRTEX method at their test side. CORRTEX consists of a long coaxial cable that is inserted into a hole parallel to the shaft that holds the nuclear explosive about 10 meters away from the test shaft. As the nuclear explosion takes place, the blast wave crushes the cable and the rate of crushing gives the explosive yield to within about 30% independent of the geological surroundings of the test site. Obviously the use of CORRTEX implies on-site inspection during nuclear tests. The presence of foreign technicans at the test site poses several difficult logistical problems. Rumor has it that drilling crews from the two rival U.S. weapons labs, Los Alamos and Livermore, have difficulty working together on closely spaced sites in Nevada.

This fall, experts from the two superpowers met in Geneva to discuss the technical issues relating to verification of test ban treaties. The discussions were reported to be frank and cordial. The U.S. delegation was lead by Robert Barker, a deputy director of the Bureau of Verification and Intelligence at the Arms Control and Disarmament Agency. Dr. Barker is a physicist from Lawrence Livermore National Laboratory who has been nominated as Assistant Secretary of Defense for Atomic Energy, the position in charge of producing nuclear explosives for the military. He is a well- known advocate of continuing an active nuclear testing program. The discussions have not yet lead to an agreement on verification issues.

Clearly, the judgement of how precise our measurements of Soviet test yields must be in order to protect us from militarily significant violations of nuclear test ban treties belong to all of us in a democracy. At the same time it is clear that this judgement must be based on an understanding the methods used to monitor the treaty and the errors inherent in this method. Science does not replace the political process but it is an important element in making national security policy.

The issue of nuclear test bans highlights the importance of having political leaders be scientifically literate. We, as teachers and scientists, must endeavor to see that our students, the future leaders of the nation, and the general voting public are equipped to evaluate these vital technical questions.

Literature Cited

1. United States Arms Control and Disarmament Agency, SOVIET NON-COMPLIANCE, February 1, 1986, p.7.

ANTHROPOLOGY

Chair: Ronald Hicks
Department of Anthropology
Ball State University
Muncie, Indiana 47306 (317) 285-1575

Chair-Elect: Michael Anslinger
Department of Anthropology
Indiana State University
Terre Haute, Indiana 47809 (812) 237-3471

ABSTRACTS

Archaeological Excavations at the Lattas Creek Site (12-Gr-29), Greene County, Indiana. C. Michael Anslinger, Indiana State University, Terre Haute, Indiana 47809——In the spring and summer of 1986 extensive archaeological excavations were conducted at the Lattas Creek Site (12-Gr-29), located in west-central Greene County, Indiana. An excess of 6,500 square meters of subplowzone area were examined, with limited deposits of intact midden being present. Cooking pits, refuse pits, hearths, human interments and post mold patters were identified. Major components consist of the Allison-LaMotte Culture and Late Woodland Albee Complex.

Progress in the Treatment of Cultural Resources in the Coal Fields of Indiana. Ruth A. Brinker, Division of Reclamation, 201 W. Main St., Jasonville, Indiana 47438.——Public interest and the active participation of avocational and professional archaeologists are the key factor in the progress which has occurred relative to cultural resources in the coal producing area of the state. This progress has taken several rather indirect pathways. Methods include a lands unsuitable for mining petition process, informal conferences between coal producers and archaeologists, and agreements between the regulatory authority (Division of Reclamation) and coal producers. Important sites preserved, temporarily avoided, or mitigated include the Beehunter Site, the Haug Sites, the Bluegrass Site, the Blanca Site, and the Flynn Site.

The federal regulatory authority (Office of Surface Mining) is currently proposing changes for rules concerning cultural resources. While state laws and regulations have not been specific on locating, identifying, and evaluating historic and prehistoric archaeological sites in the coal fields, the federal rule changes if implemented will eventually necessitate state regulatory changes. This may result in more direct and effective treatment of cultural resources.

Preliminary Report of Test Excavation of Swan's Landing Site (12 Hr 304), Harrison County, Indiana, 1986. Mark E. Cantin, Indiana University, Bloomington, Indiana 47405.——Swan's Landing Site (12 Hr 304), located along the Ohio River in southwestern Harrison County, has long been known as a deeply buried stratified Early Archaic lithic reduction station. It appears as unique due to the size of the site and the density of materials observed. Artifacts produced here include bifaces, drills, endscrapers, and Kirk points, manufactured exclusively of the locally available Wyandotte chert.

Extensive river erosion and vandalism of the site prompted test excavation by the Glenn Black Laboratory of Archaeology of Indiana University. The excavation was designed to locate intact deposits and determine site boundaries. The ultimate goal of this excavation was to recover an adequate sample of the artifactual assemblage and datable charcoal to demonstrate its unique character that would qualify it for inclusion to the National Register.

Ceramics and Ceramic Sites in the Upper Wabash Drainage: A Regional Problem. DONALD R. COCHRAN, Ball State University, Muncie, Indiana 47306.——The lack of a ceramics and ceramic sites from the Upper Wabash drainage has hampered the definition of Woodland chronologies and settlement patterns. A review of the ceramics, locations of ceramic sites, distribution of mounds, and collector site location models from the region revealed that most ceramics have been linked to Late Woodland groups associated with the Great Lakes region, most ceramic sites were located on floodplains and other river valley features, mounds were primarily distributed around the periphery of the region, and collector predictive models excluded the areas where ceramic sites were recorded. Data from the All Seasons site further indicated that many Woodland sites were likely to be buried in alluvial fans. Although the data generated through the overview was insufficient for the accurate assessment of Woodland occupation of the region, a model of Late Woodland steelement was constructed.

A Comparison of Site Frequencies and Natural Settings in the Tennyson and Shoals Survey Areas in Southwestern Indiana. JAMES W. KENDRICK AND ROBERT E. PACE, Anthropology Laboratory, Indiana State University, Terre Haute, Indiana 47809.——Systematic surveys of 100 acre areas, sampling archaeological resources in 17 southwestern Indiana counties, have found an average of one site per ten acres. However, significant differences occur between survey areas, and between different natural settings within single areas. Frequency data from recently completed surveys near Shoals in Martin County and Tennyson in Warrick County are examined, with implications for predictive models discussed.

The Yankeetown Phase: An Emergent Mississippian Cultural Manifestation in the Lower Ohio River Valley. BRIAN G. REDMOND, Glenn A. Black Laboratory of Archaeology, Bloomington, Indiana 47405.——The Yankeetown phase is the name given to a late prehistoric cultural manifestation located in the lower Ohio and Wabash river valleys of southwestern Indiana, southeastern Illinois, and northwestern Kentucky. The results of a recent study of Yankeetown settlement in this region suggest the occupation of sedentary floodplain villages, dispersed hamlets, and small extractive campsites. Previous archaeological investigations have outlined various aspects of Yankeetown material culture, subsistence, and chronology. In this paper, these data are discussed and interpreted in relation to the newly acquired settlement information. The result of this analysis is the characterization of the Yankeetown phase as an emergent Mississipian cultural manifestation.

Significant Clovis Sites in Southwestern Indiana. KENNETH B. TANKERSLEY, Indiana University, Bloomington, Indiana 47405.——Recent investigations in southwestern Indiana have identified a number of Clovis sites on a variety of landforms, including a bedrock knoll, Woodfordian Stade terraces, and sections of the Ohio River floodplain. While most sites lack primary context, the occurrence of several fluted points on a beach adjacent to stratified deposits at the Raaf site (12Sp2), presents the tantalizing possibility of an in-situ Clovis component. If the presence of a primary deposit is confirmed, this site would represent the first report of a stratified Clovis site in the central Ohio River valley.

Archaeological Research in the Coal Mining Area of Southwestern Indiana. CURTIS H. TOMAK, Indiana Department of Highways, State Office Building, Indianapolis, Indiana, 46204.——A large number of archaeological sites already have been destroyed by coal mining in southwestern Indiana, and a great many more will be destroyed by mining in that area in the near future. In view of this severe impact upon the archaeological resource base, the writer's research efforts during the past year have been devoted to the coal mining area of southwestern Indiana, in particular to the lower valley of the West Fork of White River. The work consisted of collector interviews; site survey; the test excavation of the Steele site, an Early Archaic Jerger Phase site in Daviess County; and the testing of the Thompson site, a heavily occupied Early Archaic to Late Woodland site in Greene County. Funds for the work were provided by a research grant from the Indiana Academy of Science.

Archaeological Investigation of the DeWeese-Preston House. MARY E. WAITE, HOLLY A. WAGNER AND ROBERT E. PACE, Anthropology Laboratory, Indiana State University, Terre Haute, Indiana 47809.——In a continuing investigation of the grounds of the historic DeWeese-Preston House in Terre Haute, subsurface probes and test excavations have located pathways, a trash disposal area, and other features. Excavation of an outdoor privy pit has recovered an array of artifacts that shed light on the lifestyles of the last resident.

Site Distribution and Physiographic Zones along the Big Blue River Glacial Sluiceway

FRANK N. BURKETT AND RONALD HICKS
Department of Anthropology, Ball State University
Muncie, Indiana 47306

Introduction

Between the summer of 1985 and the spring of 1986 an archaeological reconnaissance was carried out in a 25-mile corridor along the upper portion of the Big Blue River glacial sluiceway, beginning in the southern end of Delaware County, running through Henry County, and ending in the northern end of Rush County (Figure 1). This survey was

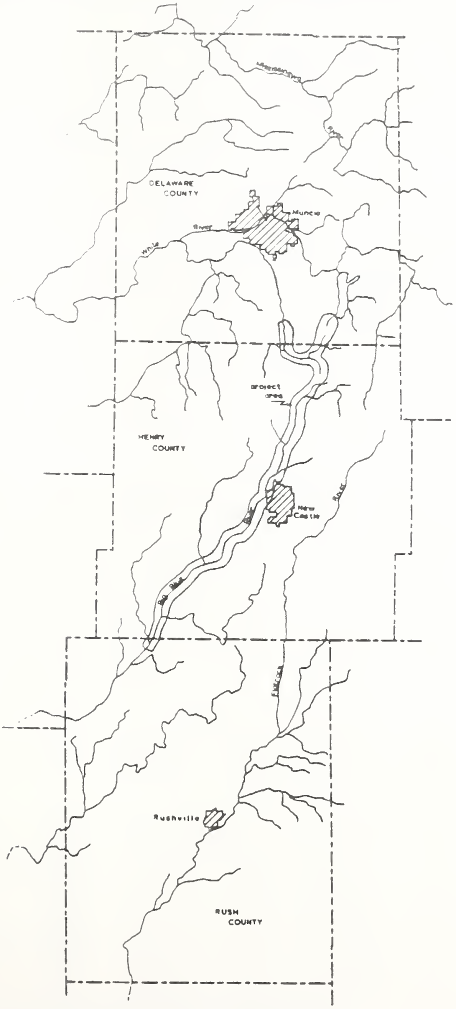


FIGURE 1. The project area within its regional context.

carried out with the aid of a Historic Preservation Fund Survey and Planning Grant administered by the Indiana Department of Natural Resources Division of Historic Preservation and Archaeology.

The Big Blue River sluiceway is located in the Tipton Till Plain physiographic unit, which has been characterized as a "nearly flat to gently rolling plain" with topographic relief provided by moraines, eskers, esker troughs, and meltwater drainageways (Schneider 1966:41, 49-50). The Knightstown Ridge Moraine transects the project area south of the Delaware/Henry County line and north of New Castle (Burger et al. 1971; Gret et al. 1972). At its highest point, this moraine rises more than seventy feet above the adjacent till plain. The project corridor was defined as encompassing the sluiceway valley plus a strip one-half this width of dissected upland (ranging generally from 50 to 100 feet higher) on either side. All told, nearly 25 square miles were included, of which a sample composed of 1090 acres, or about 7%, was actually surveyed. While the initial intention was to define survey strata using probable prehistoric biotic communities as reconstructed on the basis of soil types and physiographic features, this proved difficult owing to the vagueness of available information and was replaced by a somewhat simpler reliance on topography and types of glacial deposits, as defined by engineering and Soil Conservation Service soil maps. At the simplest level, primary zones were defined as valley and upland. On a secondary level, zones included moraine, till, kame or esker, lacustrine, muck and muck/peat/marl, terrace, and valley other (i.e., general alluvial valley deposits, not terrace, muck/peat/marl, lacustrine, or till). Also considered were transition areas where one of these zones merged into another. These areas, which we have referred to as edge zones, can be presumed to have been minor ecotones owing to differences in the vegetation likely to have developed on each kind of deposit. Edge zones were arbitrarily defined as strips 50m in width straddling a line marking the perceived junction of two secondary zones. This system represented an attempt to refine the strata used in earlier surveys. Table 1 provides a breakdown of acreage sample, by zone, as well as site and artifact densities. Table 2 further breaks this down by tertiary zones.

TABLE 1. Site and Artifact Densities by Primary and Secondary and by Edge Zones

Zone	Acres	% Total Acreage	Sites	Acres/ Site	Total Artifacts	Acres/ Artifact	Artifacts/ Site
Upland	575	52.75	150	3.83	926	0.62	6.19
Till	280	25.69	61	4.59	267	1.05	4.36
Moraine	285	26.14	84	3.39	517	0.55	6.19
Kame	10	0.91	5	2.00	142	0.07	28.60
Valley	515	47.24	79	6.69	1015	0.51	12.85
Terrace	230	21.10	46	5.23	854	0.27	18.75
Lacust.	100	9.17	20	5.00	75	1.35	3.70
MPM	105	9.63	2	52.50	48	2.23	23.50
Valley o.	80	7.33	11	7.27	38	2.16	3.36
Edges							
Upland	36	3.31	27	1.34	422	0.08	15.63
Till	14	1.28	13	1.08	110	0.13	8.38
Moraine	17	1.57	9	1.90	170	0.10	18.89
Kame	5	0.56	5	1.00	142	0.03	28.60
Valley	36	3.33	26	1.40	699	0.05	26.81
Terrace	14	1.26	17	0.81	604	0.02	35.47
Lacust.	3	0.27	5	0.60	27	0.11	5.40
MPM	11	0.96	1	11.00	47	0.23	46.00
Vo	4	0.36	3	1.33	21	0.19	7.00
Total	1090		229	4.80	1941	0.56	8.48

TABLE 2. Tertiary Zone Site and Artifact Densities

Zone	Acres	% Total Acreage	Sites	Acres/ Site	Total Artifacts	Acres/ Artifact	Artifacts/ Site
Upland							
T/M	10	1	7	1.4	54	0.19	7.7
T/Vo	4	>1	6	0.7	56	0.07	9.3
Tx	266	24	48	5.5	157	1.69	3.2
M/T	10	1	2	5.0	25	0.40	12.5
M/Vo	7	1	7	1.0	145	0.05	20.7
Mx	268	25	75	3.6	349	0.77	4.7
K/L	5	>1	5	1.0	142	0.04	28.4
Valley							
Te/MPM	8	1	10	0.8	534	0.01	53.4
K/Te/L	1	>1	1	1.2	39	0.03	39.0
Te/M	2	>1	2	1.2	19	0.11	9.5
Te/T	2	>1	4	0.6	12	0.18	3.0
Tex	216	20	29	7.5	250	0.86	8.6
L/K	1	>1	3	0.3	25	0.04	8.3
L/R	2	>1	2	1.0	2	1.00	1.0
Lx	97	9	15	6.5	48	2.06	3.1
Vo/T	4	>1	3	1.3	1	0.19	7.0
Vox	76	7	8	9.5	17	4.47	2.1
MPM/Te	10	1	1	10.0	47	0.21	47.0
MPMx	95	9	1	94.5	1	94.50	1.0
Total	1090		229		1937	0.56	8.5

Key: K = kame or esker, L = lacustrine, M = moraine, MPM = muck or muck/peat/marl, R = river edge, T = till, Te = terrace, Vo = valley other, x = nonedge

Zones and Site/Artifact Densities

Two hundred twenty-nine sites were identified, with components representing every period from Early Paleo-Indian to Late Woodland. These components included one each of Early and Late Paleo-Indian, 12 Early Archaic, 4 Middle Archaic, 3 Mid/Late Archaic, 14 Late Archaic, 3 Late Archaic/Early Woodland, 1 Early Woodland, 4 Middle Woodland, and 7 Late Woodland. Site density was greater in the uplands, but site size was greater in the valley. Further, site density was 4 times as high in edge zones compared to non-edge, while artifact densities (i.e., artifacts per acre) in the edge zones was over 20 times that in the non-edge—i.e., fewer than one artifact per acre in the non-edge zones vs. over 16 in the edge zones.

In addition, the following conclusions were reached concerning site and artifact densities:

1) Total site and artifact densities were lower than expected based on the results of earlier surveys further to the north in the Tipton Till Plain region, along the Mississinewa and Wabash rivers.

2) Kame had the greatest site and artifact densities among the upland zones while the terraces yielded the greatest densities in the valley.

3) The muck/peat/marl zone showed an exceptionally low density of sites and artifacts, which is not surprising since these soils were formed under boggy conditions.

4) In the upland, all edge zones exhibited high artifact and sites densities compared to their non-edge counterparts except moraine/till. Both till and moraine were higher. The moraine/till transition zone is the most homogenous and also the hardest to identify on the ground, which probably explains this finding.

5) In the valley, the differences between edge and non-edge were even more dramatic.

6) Site densities were highest in the edge zones where lacustrine and kame met, with terrace/till, till/valley other, and terrace/muck, peat, marl also being high. Lacustrine edges, as a group, were highest.

7) Artifact densities were highest also in the terrace/muck, peat, marl edge zone. They were also high in the areas were three zones—kame, terrace, and lacustrine—met as well in the kame/lacustrine zone. As a group, edges with a segment of terrace were highest.

8) Lowest site and artifact densities occurred in the valley non-edge zones, especially muck/peat/marl and valley other though they were also low where lacustrine deposits met the river edge.

9) Upland and valley edge zones exhibited similar site densities, but artifact densities were twice as high in the valley.

Components

Turning to components (Table 3), Early and Late Archaic points were most common, both being twice as frequent as the next group, Late Woodland. Late Woodland points were in turn nearly twice as common as the next most frequent group. The high percentages of Early and Late Archaic points resembles the results of a survey conducted along the Upper Wabash in Jay County (James & Cochran 1985). In this survey, both

TABLE 3. Components Identified by Primary, Secondary, and Tertiary Zones

Zone	EP	LP	EA	MA	M/LA	LA	LA/EW	EW	MW	LW	Uncl.
Upland			10	2	1	13	1	1	2	5	1
M			2	1		8	1	1	1	1	
T			7	1	1	2			1	2	1
K			1			3				2	
Valley	1	1	5	2	2	2	2		2	2	
Te	1	1	5	2	2	2	1		1	1	
L	1	1					1				
Vo									1		
MPM				1						1	
Total	1	1	15	4	3	15	3	1	4	7	1
% Total	2	2	28	7	6	28	6	2	7	13	2
Edge Zones											
Upland											
M/V						2			1		
M/T						1	1				
T/Vo			1								
T/M						1				2	1
K/L			1			3				2	
Total			4			13	2		2	7	2
% Total			4			13	2		2	7	2
Valley											
Te/M				1							
Te/MPM			3		1	2	1			1	
L/K		1									
MPM/Te										1	
Total		1	3	1	1	2	1			2	
% Total		2	6	2	2	4	2			4	
Total Edge		1	5	1	1	9	1	1	1	6	1
%		2	9	2	2	16	2	2	2	11	2

Key to column heads: E = Early, M = Middle, L = Late, P = Paleo-Indian, A = Archaic, W = Woodland were most frequent in the uplands (as were Late Woodland points) and were present in the valley only on terraces. Late Archaic points were much more frequently encountered in edge zones, predominantly kame/lacustrine.

Paleo-Indian points occurred only in the valley, in the lacustrine zones.

Distribution of specific point types was also interesting. For example, Kirk Corner-notched points were found most often in the till zone of the uplands. Madison points also were twice as likely to come from the uplands as from the valley.

Other conclusions concerning components include the following:

1) Early and Middle Woodland components occurred much less frequently than expected, especially given the proximity of much of the survey area to the New Castle earthworks.

2) Middle Archaic components were seldom associated with the edge zones and were less frequent than in the surveys carried out further north.

3) Point densities were greatest in the edge zones.

Artifact Classes and Materials

If we consider artifacts by classes, it can be stated that in general only minor differences were evident in their distribution (Table 4), and no conclusive distinctions could be drawn between edge and non-edge zones. The greatest percentage of initial reduction flakes occurred within the valley, perhaps reflecting the heavy dependence on glacial chert

TABLE 4. Distribution of Artifacts by Primary and Secondary Zones

Type	Upland	Valley	Till	Moraine	Kame	Terrace	Lacustrine	Muck/ Peat/ Marl	Valley Other	Total
Core	28	18	11	13	4	15	1		2	46
Bif. st. 2	3	9	2	1		8	1			12
st. 3	6	1	2	3	1	1				7
st. 4	3		2	1						3
Bif. Frag.	10	14	1	9		12	2			24
I. R. Fl.	57	84	20	27	10	65	7	9	3	141
Pr. Fl.	175	183	44	105	26	160	9	6	8	358
Sec. Fl.	11	17	2	5	4	15	1		1	28
Bro. Fl.	209	224	54	130	25	200	6	15	3	433
Bl. Fl.	24	22	10	4	10	21	1			46
Edge Mod.	188	193	54	97	37	155	21	10	7	381
Ret. Fl.	78	126	27	42	9	98	16	4	8	204
Graver	15	16	4	8	3	15			1	31
Burin	1									1
Blade	2	4	1	1		4				6
Endscpr.	9	15	1	6	2	13	1		1	24
Point	36	19	15	15	6	13	3	2	1	55
Point Frg.	21	19	3	17	1	15	1	1	2	40
Perforator	1	1		1		1				2
Bipolar	41	38	11	28	2	33	3	1	1	79
OCS	5	7	1	3	1	5	2			12
Ground St.		2								2
Blade Core		1				1				1
Denticulate	2	1	1	1		1				3
Bif. w/gvr	1		1							1
Pottery		1				1				1
Total	926	1015	267	517	142	854	75	48	38	1941
% Total	48	52	14	27	7	44	4	2	2	

from the steam bed. The till zone yielded the highest percentage of cores and points, the moraine zone the highest percentage of bipolar artifacts, and the lacustrine zone the highest percentages of biface fragments, edge-modified flakes, and miscellaneous chipped stone. The muck/peat/marl zone contained the highest percentage of initial reduction flakes and broken flakes. And the valley other zone yielded the highest percentages of most other classes. Terraces, interestingly, did not stand out in any category, perhaps indicating their place as a primary occupation area where a fairly even mix of activities was taking place. The main distinction between edge and non-edge zones is that edge modified and retouched flakes occurred much more frequently in non-edge zones.

As already suggested, the primary type of raw material used was chert from the glacial deposits, which appears in ¾ of the artifacts (Table 5). Fall Creek and Laurel cherts, available from adjacent drainage systems, accounted for another 9%. The only other cherts occurring with any frequency were Wyandotte (which was in fact slightly more common than Fall Creek), Attica, and Burlington.

TABLE 5. Comparison of Total Artifacts by Chert Type

Chert	Total Artifacts		Points		Heat-Treated	
	#	%	#	%	#	% of type
Attica	48	2	3	5	11	23
Brassfield	1	>1				
Burlington	34	2	1	2	11	32
Delaware	12	1	1	2	2	17
Fall Creek	63	3	3	5	22	35
Flint Ridge	9	>1				
Fossiliferous	16	1			8	50
Glacial	1435	75	30	55	499	35
Kenneth	2	>1				
Laurel	117	6	2	4	40	34
Liston Creek	9	>1			4	44
New Holland	2	>1				
Quartzite	4	>1				
Sugar Creek	3	>1			2	67
Unknown	83	4	7	13	27	33
Upper Mercer	14	1	1	2	4	29
Wyandotte	71	4	7	13	7	10
Zaleski	3	>1				

Heat treatment of the cherts (Table 5) appeared to be present in slightly over one-third of the examples, most commonly involving Sugar Creek, Fossiliferous, and Liston Creek materials. Wyandotte and Attica, the most common of the exotics, were the least likely to be heat treated, reinforcing the assumption that they were brought in because of their better flaking qualities. Heat treatment occurred most frequently in points of the Paleo-Indian and Late Archaic periods. The percentage of heat-treated points almost exactly matched the percentage for total artifacts.

Local glacial cherts were most commonly used for points of all periods except Early and Middle Woodland (Table 6). Wyandotte was the second most common material for points, especially for the Early Archaic, Late Archaic/Early Woodland, and Middle Woodland periods. Attica, the third most frequent type, was well represented among Early and Middle Archaic points. Fall Creek and Laurel cherts were less frequently used for points than either Attica or Wyandotte. Upper Mercer chert occurred only in a single Early Archaic point while Burlington occurred only in a single Early Woodland point

TABLE 6. Comparison of Points by Component and Chert Type

Chert	EP	LP	EA	MA	M/LA	LA	LA/EW	EW	MW	LW	Un	To.
Attica			2	1								3
Burl.								1				1
Del. (ht)						1						1
Fall Cr.			1			1						2
F.C. (ht)									1			1
Glacial			4	1	2	3	1			3	1	15
Gl. (ht)		1	1	1		7	1		1	3		15
Laurel			1							1		2
Unk.			1	1	1	2						5
Unk. (ht)	1				1							2
Up. Mer.			1									1
Wyan.			4				1		2			7
# Heat Td	1	1	1	1		9	1		2	3		19
% Tot.	2	2	27	7	5	27	5	2	7	13	2	
% Exotic		100	45	25			33	100	50			24
% Gl. (loc.)		33	50	67	67	67	0	25	86	100	55	
% Semi-loc.		13	0	0	7	0	0	25	14	0	9	

and Delaware in one Late Archaic specimen. In general, Early Archaic, Early Woodland and Middle Woodland points were more often manufactured of exotic than local or semi-local cherts.

Pottery was found on only the Van Nuys Site and a second site near it, just north of New Castle.

Summary

In summary, the survey of the Upper Big Blue River glacial sluiceway demonstrated a preference for edge zones for site location, a variation in the pattern of site distribution from period to period, and a tendency for the largest sites to be on the terraces along the valley edges. Differences could also be observed in the choice of raw materials and in the use of heat treatment from period to period. A more detailed discussion will appear in the full report, to be published in the Ball State Archaeological Resources Management Service Reports of Investigations series.

Literature Cited

Burger, A., et al. 1971 Geologic map of the 1 x 2 Muncie quadrangle, showing bedrock and unconsolidated deposits. Indianapolis: Department of Natural Resources.

Grey, W., et al. 1972 Geologic map of the 1 x 2 Cincinnati quadrangle, showing bedrock and unconsolidated deposits. Indianapolis: Department of Natural Resources.

James, Mary Lou, & Donald R. Cochran. 1985. An archaeological survey of Jay County, Indiana. Ball State University Archaeological Resources Management Service Reports of Investigations 18.

Schneider, Allan F. 1966 Physiography. *In* Natural Features of Indiana, Alton A. Lindsey, ed., pp. 40-55. Indianapolis: Indiana Academy of Science.

The 1986 IU/GBL Excavations at the Stephan-Steinkamp Site (12Po33)

SHERRI L. HILGEMAN AND MARK R. SCHURR
Department of Anthropology
Indiana University and Glenn A. Black Laboratory of Archaeology
Bloomington, Indiana 47405

The 1986 Indiana University/Glenn A. Black Laboratory of Archaeology archaeological fieldschool was held at the Stephan-Steinkamp site (12Po33) in southeastern Posey County, Indiana. This Mississippian site is located on a slight floodplain ridge approximately 300 feet (91.7 meters) north of the Ohio River. The site provided information on the relationship between surface artifact distributions and subplowzone contexts, produced an excavated collection of early Angel phase ceramics, and material from excavated contexts suitable for radiocarbon and thermoluminescence dating.

Earlier Surveys of the Site

The first recorded comments on 12Po33 were made by George and Francis Martin of Newburg, IN (GBL Site Survey Files). They noted that many pits had been washed out in 1963 and that the site was similar in size to another nearby Mississippian site, the Caborn site (12Po32). In 1964, Dr. James Kellar reported that 12Po33 was located on a slight rise in the floodplain and that plowing on the edge of an erosional depression was exposing material in context. Kellar also noted that there were differences in the shell-tempered ceramic assemblages of 12Po33 and 12Po32. A higher proportion of cordmarked pottery was present at 12Po33.

Noel Justice (GBL) and Charles Lacer (of Evansville, IN) surveyed the site in 1978 and recorded the presence of Yankeetown and Middle Woodland components. Justice confirmed the presence of these non-Mississippian components in 1979 when he examined a deflated area on the east end of the site.

The site was visited several times in 1985 by individuals from Indiana University and the University of Southern Indiana participating in an intensive survey of the Caborn site. Dark areas of soil indicated that features were being exposed by cultivation. Aerial photographs taken by Marcia Yockey, meteorologist at WFIE-TV, Evansville and Alan Coville, also of Evansville, IN, clearly showed a circular pattern of dark stains at the site. Other stains were also present outside this circular area.

Surface Collections

The 1986 investigations consisted of controlled surface collections of a portion of the site, and excavations within that portion. A north-south transect 60 ft (18.3 m) wide and 460 ft (140.2 m) long on the western edge of the Stephan property was leased, left unplanted, and sprayed with herbicide to control vegetation. The transect was divided into 20 ft x 20 ft (6.1 m x 6.1 m) surface collection units. All objects larger than 1 cm^2 in each 400 ft^2 ($37.2m^2$) surface collection unit were collected and all observed surface features were mapped. The limit of the surface scatter of shell-tempered sherds outside the transect was then defined and related to topographic contours and natural features.

The site boundary, as defined in the summer of 1986 by the surface distribution of shell-tempered sherds, is irregular (Figure 1), and encloses an area of 2.8 ha (6.92 acres). This is much larger than the 0.25 to 1.0 ha (.62 to 2.47 acre) estimate reported by Green (5). Justice and Lacer estimated site dimensions of 900 ft x 600 ft (274 m x 183 m) which yield an estimated area of 3.94 ha (9.74 acres), assuming an elliptical shape. The observed surface distribution of sherds is not an accurate indicator of sub-plowzone contexts, since the surface distribution of shell-tempered sherds is partially a product

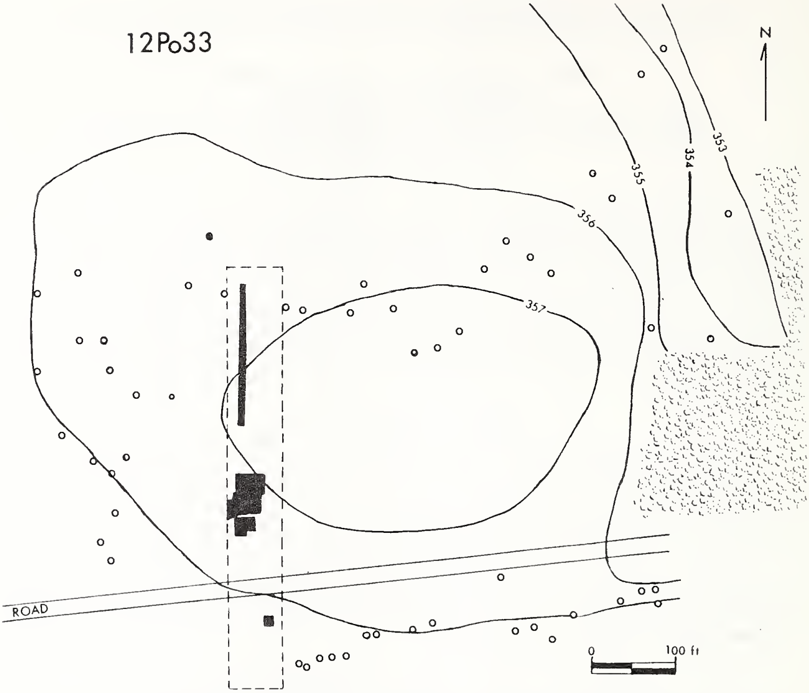


FIGURE 1. Site Map. The dotted line encloses the transect, the black areas indicate excavated blocks and the backhoe trench, and the open circles indicate the limits of the surface distribution of shell-tempered pottery.

of cultivation and erosional exposure and transport. It may also represent the overlapping of two or more temporally discrete Angel phase occupations. The limitations of surface surveys have been recognized as complicating factors in studies of Mississippian settlement patterns in the area (6).

The relationship between the surface density of shell-tempered sherds and sub-plowzone deposits in the transect is shown in Figure 2. The transect contained 21 surface collection units along its north-south axis by 3 surface collection units along its east-west axis. The average masses of shell-tempered sherds for each set of three surface collection units on an east-west axis (except for those containing the road) are represented by the bars of the histogram. The mean mass of sherds for all units ($\overline{X}$) and one standard deviation (s) on either side of the mean are shown in the right margin. The limits of the surface distribution of shell-tempered sherds ("sherd limits") and the location of the feature exposed by the backhoe trench which may represent a stockade ("stockade?") are shown at the bottom of the histogram.

If the surface distribution of sherds across the site follows a Poisson distribution, then it would be reasonable for the limits of the surface distribution of shell-tempered pottery to correspond to the point where the mean sherd mass is less than $\overline{X}$-s, since $\overline{X} = s^2$ for a Poisson distribution. It would also be reasonable for a stockade line to correspond to the point where the sherd mass drops below $\overline{X}$. These conditions seem to hold true for the transect survey. Though a Poisson distribution can strictly be applied

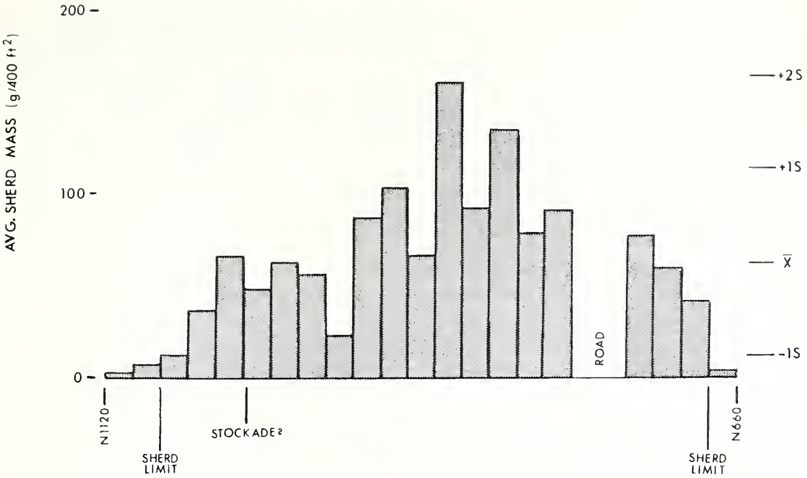


Figure 2. Distribution of the average masses of shell-tempered sherds by surface collection unit along the north-south axis of the transect.

only to discrete variables, and mass is a continuous variable, the distribution of sherd mass across the site may approximate a Poisson distribution because sherd mass is a function of the *number* of sherds and sherd mass was measured to the nearest whole gram.

Excavations

The surface collections were washed and sorted in the field, and choropleth and surface feature maps were prepared. Excavation units were then placed to evaluate both high densities of surface artifacts and some observed surface features. A total of 1000 ft^2 (99.9m^2) were opened by hand and an additional area 800ft^2 (74.3 ^{2}) was stripped of plowzone by backhoe and mapped.

The excavated blocks uncovered portions of at least four houses (Fea. 8, 9, 17, and 18), two associated pits (Fea. 2 and 3), and a dog burial (Fea. 4) (Figure 3). One large bath tub-shaped pit (Fea. 2) produced wood charcoal from a hardwood log which gave a radiocarbon date of 1230 + 60 BP, Beta-17509 (AD 625 - 895, corrected after (9)). Two shell-tempered sherds from a globular jar from this same pit yielded thermoluminescence dates of 940 + / – 160 BP, AD 1010 (Alpha-3085) and 860 + / – 230 BP, AD 1090 (Alpha-3086)); this gives a mean date of AD 1050 with a pooled variance of + / – 280.

Charred botanicals were well preserved. The grain structure of wooden timbers, a fragment of reed mat, and a corn cob were clearly observed in-situ. Bone preservation was generally poor, except for a pit (Fea. 3) which contained large quantities of mussel shells. Only the most durable parts of the dog burial were recovered intact.

Artifact Assemblage

The non-ceramic artifacts recovered from excavated contexts are generic Mississippian types. The chipped stone assemblage includes Madison points (13), simple flake tools, and debitage of local pebble cherts. Hoe flakes of imported Mill Creek and Dover cherts were also recovered. Ground stone artifacts from the excavated units are restricted to fragments of sandstone slabs, although two discoidals were recovered during the site boundary survey.

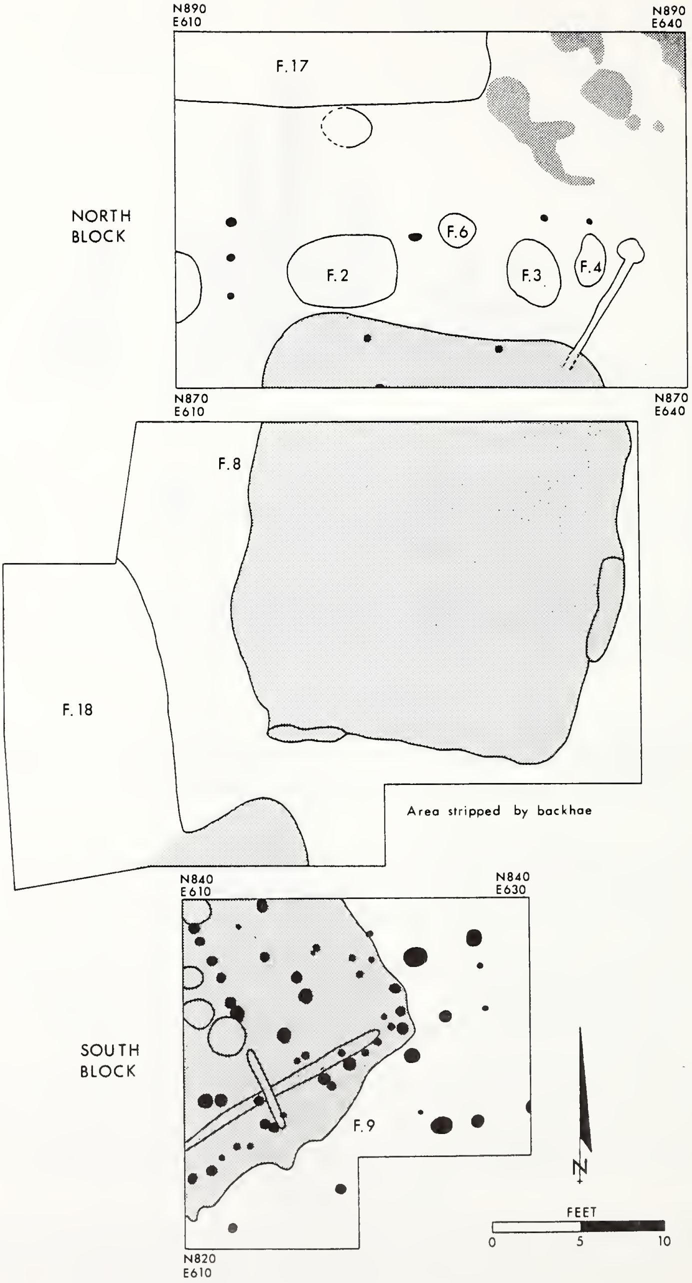


FIGURE 3. The excavated blocks at 12Po33 showing tested house basins (Fea. 8 and 9), portions of two other house basins (Fea. 17 and 18), and other features (Fea. 2, 3, 4, and 6). Solid black circles denote postholes.

The diagnostic characteristics of the ceramic artifacts can be used to place the site more precisely within the Mississippian period. Sherds less than ¼ inch (0.64 cm) in diameter and those on which the exterior is no longer intact were excluded from this analysis. Percentages in the following discussion are based on total weight in grams, rather than on count, and on the excavated collection.

The Mississippian shell-tempered pottery sherds make up approximately 99.1% of the total excavated ceramic assemblage. The remainder of the assemblage consists of grog-tempered sherds, the diagnostic sherds of which are Yankeetown incised and bar-stamped. These grog-tempered sherds appear to represent a Yankeetown occupation of the site area (2).

The paste of the shell-tempered ceramics varies, but it generally contains sufficient sand and/or grit to give the sherds a slightly to moderately sandy feel. It seems unlikely that the sand/grit is a deliberate inclusion as temper, but probably instead reflects the type or quality of the clay used in pottery manufacture. The shell temper varies from moderately fine to coarse, conforming to typical Mississippi Plain ware, and does not approach the quality of Bell Plain (10, 11).

Diagnostic aspects of the Mississippian assemblage include: relative proportions of different surface treatments; and other vessel treatments which include additions of handles, nodes and lugs, lip notching, and color. From the earliest surface surveys of the site, the occurrence of significant quantities of cord-marked body sherds (in addition to the usual plain and fabric-impressed) has been regarded as important. In the total excavated collection, cord-marked body sherds represent approximately 4.6% of the collection; when the plain, fabric-impressed, and cord-marked *body sherds* are compared, the cord-marked sherds make up approximately 5.7% of the total body sherds, the fabric-impressed 4.9%, and the plain 89.4%. These percentages differ somewhat in North Block as compared to South Block (Figure 4), but these differences do not appear significant.

One of the recognizable vessel forms is the standard Mississippian globular jar with a constricted neck, everted or out-flaring rim, and squared-off lip. Cord-marking, when it occurs, begins on the shoulders of such jars, just below the neck. This is why comparisons of the proportion of cord-marked sherds must be restricted to body sherds. While the type designation is not being used here, these cord-marked jars are generally similar to Cahokia Cord-marked vessels (7, 14). Other recognizable vessel forms include the fabric-impressed "salt pan" and a variety of plain-surfaced, straight to out-flaring rimmed bowls.

Other vessel "treatments" are less common but still very important for characterizing the Mississippian ceramic assemblage. These include the nodes/lugs, handles, notched bowl lips, and red-slipping.

Sixteen examples of nodes and lugs were recovered by excavation. All but one of these represent the addition of single clay nodules to the exterior of the rim at or just below the lips of bowls and jars. A single example represents a line of three nodes on an outflaring jar rim. Other noded sherds are too fragmentary to determine whether these occur singly, in pairs, or in larger multiples.

Two loop handles attached to out-flaring jar rims are diagnostically important. These handles have cylindrical cross-sections and are attached at the top of the lip and at just below the neck constriction. At least one of these two jars was cord-marked. There are also portions of two detached strap handles. One of these appears to be plain, but the other has a wide, shallow groove running vertically along the exterior of the strap.

Two more purely decorative treatments were identified. Two rim sherds exhibit notching on the vessel lip; one of these appears to be an out-flaring bowl. There are also a few red-slipped sherds from vessels of unknown form.

The Site within the lower Ohio Valley

The termoluminescence dates from this site suggest that this ceramic assemblage

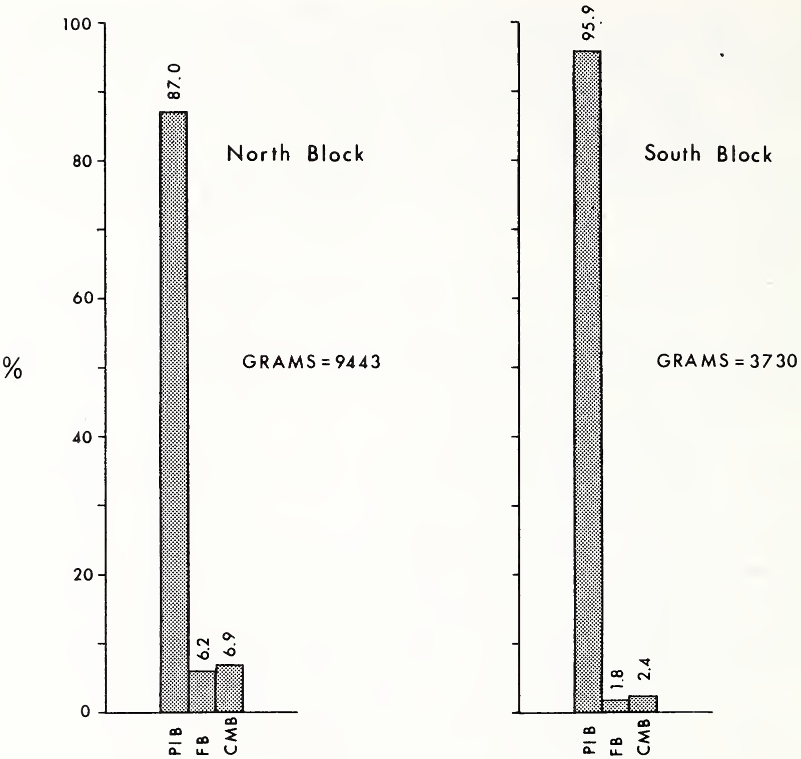


FIGURE 4. Relative proportions of the three primary surface treatments by excavation block (P1B = plain body sherds, FB = fabric-impressed body sherds, CMB = cord-marked body sherds).

dates to the 11th century AD. This placement is corroborated by the assemblage's general similarities to those which have been assigned to the Jonathan Creek phase in the lower Tennessee-Cumberland drainage in western Kentucky. This phase is also tentatively placed in the 11th century AD (3, 12, 15 esp. Figures 42-46). The Jonathan Creek phase ceramic assemblage has been described as extremely plain, as it does not include the incising, engraving, punctating and negative painting so well known for the lower Ohio Valley Mississippian sites. The Jonathan Creek phase assemblage is characterized by fabric-impressed "salt pans" and vessel surfaces which are primarily plain but with limited quantities of cord-marking and red-slipping. The common, recognized vessel forms are relatively small globular jars with loop handles.

The sites of the Jonathan Creek phase seem to represent the earliest Mississippian occupations in the lower Tennessee-Cumberland and adjacent portions of the Ohio Valley; similarily 12Po33 probably represents the earliest Mississippian occupations within the Angel phase (8) of the southwestern Indiana portion of the Ohio Valley. The Jonathan Creek phase and the as-yet unnamed phase represented here by 12Po33 are also similar in that their relationships to the later Kincaid (4) and Angel (1) sites, respectively, are unclear. Certainly, later in time, Kincaid and Angel's political hegemony would encompass each respective area.

Acknowledgments

Funding for the 1986 field season at the Stephan-Steinkamp site was provided by Indiana University, the Glenn A. Black Laboratory of Archaeology, and the Indiana Historical Society. The project was directed by Dr. Christopher S. Peebles, Director of the Glenn Black Lab. We would also like to thank Mr. John Stephans, Mr. Wayne Adams, and Mr. Ronald Steinkamp for permission to work on their properties, and Wilbur and Faye Pate and Mike, Donna, and Carl French who allowed us to enjoy their river camps. We were happy to receive frequent visits and helpful advice from Frances Martin, Charles Lacer, and Marjorie Jones. Our old and new friends, John and Mickey Williams, Frances Weinberg, Lynn Schurr, Kip Henning, Richard Clark, Leon Hostetler and Jeff Brown, volunteered much of their valuable time. We hope they enjoyed themselves.

The field crew consisted of Greg Angermeier, Linda Pride, Eugene Wegener, and Bruce Eisterhold from the University of Southern Indiana; Laurie Brown from the University of Evansville; Shawn French, Nancy Henning-Clark, Bartlett Meeks, Thomas Minichillo, Mark Moore, Julie Morgan, Lynette O'Brien, and Jennifer Walters from Indiana University; and Atalanta Franz, Detlef Gronenborn, and Vincenz Leppert from the Johan Wolfgang Goethe Universitat, Frankfurt am Main, the Federal Republic of Germany. Many thanks to all of them.

Literature Cited

1. Black, Glenn A. 1967 Angel Site: An Archaeological, Historical, and Ethnological Study. Indiana Historical Society, Indianapolis.
2. Blasingham, Emily. 1953 Temporal and spatial distribution of the Yankeetown cultural manifestation. MS Thesis, Department of Anthropology, Indiana University, Bloomington.
3. Clay, R. Berle. 1979 A Mississippian Ceramic Sequence from Western Kentucky. Tennessee Anthropologist 4(2): 111-128.
4. Cole, Faye-Cooper, Robert Bell, John Bennett, Joseph Caldwell, Norman Emerson, Richard MacNeish, Kenneth Orr, and Roger Willis. 1951 Kincaid: A Prehistoric Illinois Metropolis. University of Chicago Pres, Chicago.
5. Green, Thomas J. 1977 Economic relations underlying Mississippian settlement patterns in southwestern Indiana. Ph.D. dissertation, Department of Anthropology, Indiana University, Bloomington.
6. Green, Thomas J. and Cheryl A. Munson. 1978 Mississippian settlement patterns in southwestern Indiana. In Mississippian Settlement Patterns, edited by Bruce D. Smith. Academic Press, New York. pp. 293-330.
7. Griffin, James B. 1949 The Cahokia Cermaic Complexes. In Proceedings of the Fifth Plains Conference for Archaeology, edited by John L. Champe. Laboratory of Anthropology, University of Nebraska, Notebook 1: 44-58.
8. Honerkamp, Marjory W. 1975 The Angel Phase: An Analysis of a Middle Mississippian Occupation in Southwestern Indiana. Ph.D. dissertation, Department of Anthropology, Indiana University, Bloomington.
9. Klein, Jeffry, J.C. Lerman, P.E. Damon, and E.K. Ralph. 1982 Calibration of radiocarbon dates: tables based on the consensus data of the Workshop on Calibrating the Radiocarbon Time Scale. Radiocarbon 24: 130-150.
10. Phillips, Phillip. 1970 Archaeological Survey in the Lower Yazoo River Basin, Mississippi, 1944-1955. Papers of the Peabody Museum of Archaeology and Ethnology No. 60, Cambridge, Massachusetts.
11. Phillips, Phillip, James A. Ford, and James B. Griffin. 1951 Archaeological Survey in the Lower Mississippi Valley, 1940-1947. Papers of the Peabody Museum of Archaeology and Ethnology No. 25, Cambridge, Massachusetts.

12. Riordan, Robert V. 1975 Ceramics and Chronology: Mississippian Settlement in the Black Bottom, Southern Illinois. Ph.D. dissertation, Department of Anthropology, Southern Illinois University, Carbondale.
13. Scully, E.G. 1951 Some central Mississippi Valley projectile point types. Mimeographed paper, Museum of Anthropology, University of Michigan.
14. Vogel, Joseph O. 1975 Trends in Cahokia Ceramics: Preliminary Study of the Collections from Tracts 15A and 15B. In Perspective in Cahokia ARchaeology, pp. 32-125. Illinois Archaeological Survey, Bulletin No. 10, Urbana.
15. Webb, William S. 1952 The Jonathan Creek Village, Site 4, Marshall County, Kentucky. University of Kentucky, Reports in Archaeology and Anthropology, Vol. 8, No. 1 Lexington.

A "Partial Cremation" from the Angel Site, Vanderburgh County, Indiana

Mark R. Schurr
Department of Anthropology, Indiana University
Bloomington, Indiana 47405

Introduction

The Angel Site (1), Vanderburgh County, Indiana, was an important regional center for the Angel-phase Mississippian culture which occupied the Ohio River valley of Indiana during the late prehistoric period (after A.D. 1000 and before the historic period). The 40 hectare site was enclosed by a bastioned stockade and contains several flat-topped pyramidal mounds and a plaza. It is now protected as a state memorial. Over twenty years of excavation at Angel, directed by Glenn A. Black, recovered abundant and varied material remains and demonstrated that portions of the site were intensely occupied. Because of the great complexity of the occupations at Angel, many aspects of the site are still poorly understood.

Excavations at Angel produced over 300 "burials" consisting of an unknown but greater number of individuals. Most of the burials at Angel were flesh inhumations in a variety of body positions and orientations, though secondary interments have also been recognized (1: 531-537). Of these 300 burials, only six show signs of burning. One of these, Burial 4 from subdivisions R12A and R11D, was described as unorthodox, aberrant, and inexplicable because this extended burial of a robust male aged 30 - 40 was thought to have been deliberately burned at the right maxillary, the right illium, and the right foot, a pattern of "partial cremation" which is apparently unique at Angel (1: 337-385).

Burial 4 R12A/R11D

The skull of Burial 4 R12A/R11D was first encountered near the end of the 1957 field school during test excavations of the "talus" slope on the east side of Mound A (Figure 1). Three blocks in subdivision R12A were excavated to determine if the slope was the result of historic period disturbances or was prehistoric in origin. The test showed that the area was the product of prehistoric activities and that it had not been disturbed except by plowing. The skull of Burial 4 R12A/R11D intruded into the northern edge of subdivision R12A and was remarkable because a pot was located at the left shoulder and the right side of the skull had apparently been burned in situ. Excavations were later extended into subdivision R11D to recover the rest of the burial (1: 337-385).

After the blocks containing the entire burial were cleared, it was apparent that a fully articulated individual had been placed within a grave dug into the floor of a semi-subterranean house. The grave was oriented parallel to one wall of the structure. The right side of the body had been charred on the right side of the face, the shoulder, the pelvic region, and the lower leg and foot. Charcoal and hard clay "around and amid the bones" was interpreted as an indication that the burial had been burned in the grave (1: 383).

Examination of the curated material from Burial 4 R12A/R11D shows that all the burned bone from this burial was "smoked" in patterns consistent with the burning of a fully articulated skeleton still connected together with ligaments. The bones of the lower right leg and foot are smoked on their ventral sides with very heavy smoking on the shin and tops of the tarsus and metatarsals. There is very light smoking or none at all on the articular surfaces of the joints of the ankle and foot. The phalanges of the right foot are unburned except for the superior surface of the first phalange of the big toe. A similar pattern of burning is also seen on the right lower arm, wrist, and hand. The most heav-

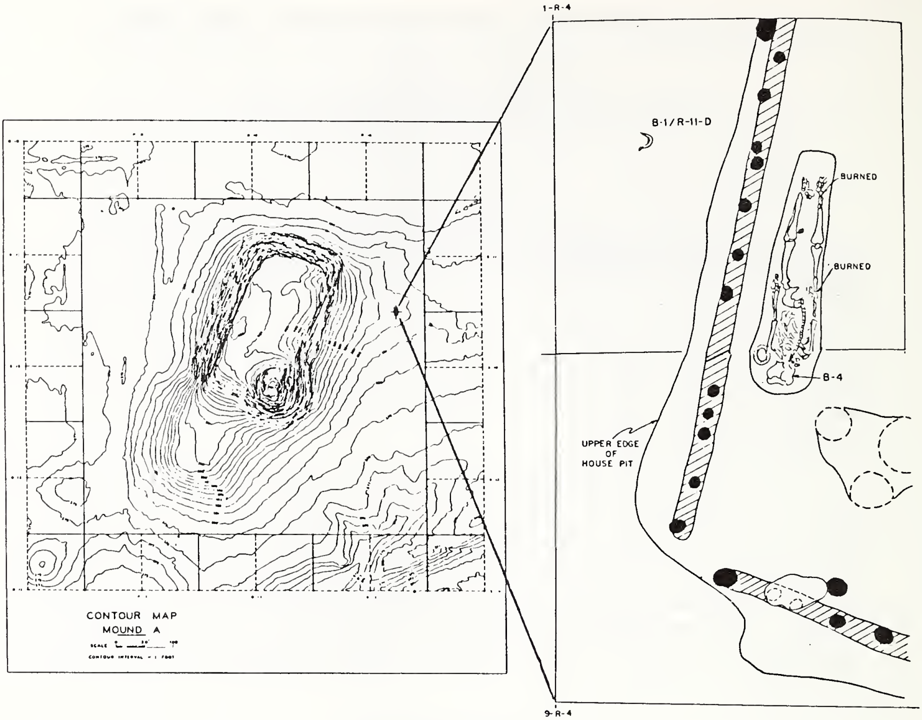


FIGURE 1. Location map of Burial 4 R12A/R11D. (Adapted from Black 1967: 37, 381, 382).

ily smoked portions of the lower right arm correspond well with the arm's placement adjacent to the right side of the pelvis.

The skull is heavily scorched in the facial region, especially on the most anterior portions of the maxilla and the mandible. The incisors, canines, and premolars of both the upper and lower dentition are badly fragmented and have broken off, leaving only the roots intact within their sockets. Both the upper and lower molars suffered less damage from heat. They are scorched but have been retained intact in their sockets. Fragments of what appears to be charred flesh were recovered from beneath the mandible, and the right gonial angle of the mandible is unsmoked with a relatively sharp demarcating line between the smoked and unsmoked portions of the mandible. The frontal bones are also smoked, with a gradual decrease in intensity toward the top of the vault. The scorched area extends onto the partietal on the right side but not on the left.

Though Black reported that parts of the post-cranial skeleton were partially calined, the cataloged material from this burial stored in Packing Case 1103-2 does not include any calcined bone according to the definition of calcined bone used by Goldstein and Buikstra (4). However, portions of this skeleton are apparently missing from the collection, including the right illium, the rib cage, right scapula, and the proximal ends of the right humerus and ulna. Photographs of the burial prior to removal show that all of these bones with the exception of the left side of the rib cage were in poor condition so they may have disintegrated on removal or subsequently. Smoked bones are apparent in the photographs but calcined bones are not.

A possible interpretation of Burial 4 R12A/R11D

This burial shows few of the characteristics which make deliberate cremation a probable mortuary treatment. The low level of oxidation of the anterior surfaces of the skeleton is consistent with similar patterns on partially burned articulated extended burials from Mound 2 at the Yokem site, where a charnel house containing open graves was apparently burned (5). The restriction of the burned areas to the right side of the skeleton is probably a result of its placement in the structure with the left side adjacent to a wall and therefore partially protected.

The "partial cremation" of Burial 4 R12A/R11D may have been accidental if the structure containing the burial accidentally caught fire while the individual was interred and the grave was still open. Accidental burning has been used to explain incomplete "cremations" from Illinois Hopewell sites (2). Given that fleshed inhumations in house floors are common in the excavated village area at Angel, and that ethnographic accounts cited by Black (1: 273-281, 531-537) often describe the presence of fires within structures used for mortuary purposes, an accidental fire does not seem impossible. Alternately, the burning of Burial 4 may have been accidental in the sense that it was incidental to the deliberate burning of a charnel house as part of the mortuary ritual. Burned charnel houses located in or on small mounds have been identified at Mounds 2 and 3 at the Yokem Site (5) and at the early phases of the Kincaid Site (3) which is very similar to Angel. The location of the structure at Angel on an artificially raised area adjacent to Mound A may be significant.

Conclusions

A reanalysis of Burial 4 R12A/R11D from Angel using more recent sources unavailable to Black suggests that the pattern of burning on this burial may not have been intentional and that it can best be explained by the burning of the structure housing the burial while the burial was in the grave but still exposed. Accidental or deliberate burning of a domestic structure temporarily used for mortuary functions or of a charnel house are possible interpretations which could only be evaluated by additional excavations to see if the simultaneous burning of multiple burials expected for a charnel house are present in the unexcavated portions of the structure.

Literature Cited

1. Black, G.A. 1967. Angel Site: An Archaeological, Historical, and Ethnological Study. Indiana Historical Society.
2. Buikstra, J.E. 1975. Hopewell in the Lower Illinois Valley. Northwestern Arch. Program Scientific Papers No. 2, p. 15.
3. Cole, Fay-Cooper. 1951. Kincaid: A Prehistoric Illinois Metropolis. University of Chicago Press, Chicago, p. 131.
4. Goldstein, L. and J.E. Buikstra. 1973. The Perrins Ledge Crematory. Ill. State Museum Report of Inv. No. 28. Ill. State Museum, Springfield.
5. Perino, G.H. 1971. The Yokem Site, Pike County, Ill. In Mississippian Site Archaeology in Illinois I, Ill. Arch. Survey Bull. No. 8, pp. 149-186.

Acknowledgments

The author wishes to thank Dr. Della Collins Cook for her encouragement and advice, Dr. James Kellar and Dr. Christopher Peebles for access to the skeletal material, and Sherri L. Hilgeman for uncovering interesting aspects of Burial 4 R12A/R11D.

BOTANY

Chair: Gail E. Ruhl
Department of Botany and Plant Pathology
Purdue University
West Lafayette, Indiana 47907 (317) 494-4641

Chair-Elect: K. Michael Foos
Department of Biology
Indiana University East
Richmond, Indiana 47374 (317) 966-8261 ext. 303

ABSTRACTS

Changes in Host-nuclear Macromolecules in Resistant and Susceptible Barley to Infection by *Erysiphe graminis* f. sp. *hordei* Culture CR3. Pradeep K. Bhattacharya, Indiana University Northwest, Gary, Indiana 46408.——The effects were cytofluorometrically determined of infection with CR3 culture of *Erysiphe graminis* f. sp. *hordei* on the levels of nuclear DNA, RNA, histone, non-histone, and total protein and on the size of the nuclei in the near-isogenic lines of resistant and susceptible barley coleoptile cells. Nuclear size, RNA, and non-histone protein content increased and histone content decreased by 18 hours after inoculation in both varieties, but the observed changes occur more rapidly after inoculation in the resistant variety than they do in the susceptible variety. DNA content decreased from 64 hours after inoculation. These results are similar to those reported for wheat rust system and indicate that profound changes in nuclear metabolism are induced by infection with the biotrophic fungi.

Optimum Growth Temperatures for *Pilobolus*. K. Michael Foos and Judith A. Royer, Department of Biology, Indiana University East, Richmond, Indiana 47374.——Optimum growth temperatures for *Pilobolus* have not been published in the literature. Most studies of *Pilobolus* growth reported in current as well as older papers have been done at "room temperature." This indicates a widely held belief that its optimum temperature for growth is "room temperature" (20-24 C). Rarely are isolates of *Pilobolus* incubated at temperatures above 25 C. This study of six isolates of *Pilobolus* indicates that these fungi grow actively in a range of temperatures between 5 and 40 C, and that the optimum temperature commonly lies between 30 and 35 C.

***Verticillim dahliae* as a Biocontrol Agent of Velvetleaf *Abutilon theophrasti*.** R.J. Green, Jr. and G.L. Wiley, Department of Botany and Plant Pathology, Purdue University, West Lafayette, Indiana 47907.——*Verticillium dahliae* appeared naturally in stands of velvetleaf (VL) *Abutilon theophrasti* in soybean/weed competition studies. Within three years, suppression of VL was almost 100% and the weed was non-competitive with soybeans. VL plants with symptoms were 97% infected and 84% of all plants without symptoms yielded *V. dahliae*. The soybean/weed competition studies were based on different weed population densities, row width and tillages. None of these variables had a measurable effect on soil populations of *V. dahliae*. Greenhouse studies showed initial host specificity of VL isolates of *V. dahliae*, however, serial passage of isolates through a number of test plant species, including soybean, showed that host specificity could be altered. The implications of this instability will be discussed in consideration of *V. dahliae* as a potential biocontrol agent.

Efficiency and Pattern of ^{65}Zn Incorporation into Soybean Seeds by Root Absorption, Stem Injection, and Foliar Application. Alam Khan and C.M. Weaver, Department of Foods and Nutrition, Purdue University, West Lafayette, Indiana 47907.——— Hydroponically grown soybeans were intrinsically labeled with ^{65}Zn by root absorption, stem injection, and foliar application to see whether the method of labeling affects the efficiency of ^{65}Zn incorporation and distribution of Zn in seeds. The efficiency of root absorption of ^{65}Zn was the lowest (23.44%), foliar application was intermediate (37.85%) and stem injection was the highest (64.50%). Subcellular distribution of ^{65}Zn in seeds indicated few differences among the different labeling techniques. Solubility of ^{65}Zn from seeds labeled via root absorption, stem injection and foliar application was 66.83, 73.91, and 73.65% of the total flour ^{65}Zn respectively. More than 80% of the soluble ^{65}Zn activity remained in the supernatant at pH 4.5 regardless of the labeling techniques. About 16-20% of the supernatant ^{65}Zn was not dialyzable. The dialyzable ^{65}Zn is either free or attached to phytic acid, protein, or fiber which have low molecular weight. Thus, initial separation of soybean components containing ^{65}Zn did not reveal any difference due to labeling technique.

Incidence and Control of Cucurbit Powdery Mildew in Indiana. Richard X. Latin, Purdue University, West Lafayette, Indiana 47907.———Powdery mildew threatens production of muskmelons, pumpkins and squash each year. The disease defoliates plants and results in decreased yields and reduced fruit quality. Two species of powdery mildew (*Erysiphe chicoracearum* and *Sphaerotheca fuliginea*) were identified in Indiana in 1986. *E. chicoracearum* was detected in locations in Tippecanoe and Monroe counties. Incidence of *S. fuliginea* was more widespread. Samples of mildew-infected leaves collected from commercial muskmelon, pumpkin, and squash fields in 17 counties yielded conidia of *S. fuliginea*.

Control of mildew on other cucurbits is achieved with applications of systemic fungicides. In experimental field plots of muskmelons and pumpkins, traditional systemic fungicides such as benomyl performed poorly; while relatively new compounds such as triadimefon provided excellent control under severe disease pressure.

Ultrastructure of Articulated Laticifers in *Stapelia bella* (Asclepiadaceae). Thomas E. Maxam and Kathryn J. Wilson, Indiana University-Purdue University, Department of Biology, P.O. Box 647, Indianapolis, Indiana 46223.———The ultrastructure of articulated laticifers in stems of *Stapelia bella* was studied. Articulated laticifers form a coherent system of branching cells, whose cross walls rarely breakdown, and that are located near vascular tissue and nonarticulated laticifers in the stem. Large tissue pieces were prefixed for 48 hrs. and small pieces excised and fixed in a Modified Karnofsky's Fixative for an additional 18 hrs. Tissue was postfixed in 2% osmium tetroxide, dehydrated to pure acetone, and embedded in Spurr resin. Articulated laticifers possess a dense peripheral cytoplasm around a large central vacuole. Plasmodesmata are common. The plasma membrane is highly convoluted producing a vesicular outer cell boundary. Rough endoplasmic reticulum occupies the cytoplasm in concentric rings. Leucoplasts and mitochondria are present. A most unusual feature is a highly convoluted multiple membrane system commonly present in place of a tonoplast.

Aquatic Plant Distribution and Mapping of Selected Ponds of Miller Woods, Indiana Dunes National Lakeshore. Peggy L. Ruckman and Richard L. Whitman, Department of Biology, Indiana University Northwest, Gary, Indiana 46408.———The interdunal ponds of the Miller Woods area were mapped during 1984-85 as part of a larger organismal study. These ponds lie in a topography of ridges and swales, and may be classified as mature to pre-senescent. Pond surface area, perimeter and shoreline development were determined for vernal, aestival and semi-permanent ponds within the study area. Aquatic plant distributions were mapped for three semi-permanent ponds (Ponds 30, 33 and 35) in the vicinity of the Douglas Environmental Education Center. The most important plant in the marginal zones was *Carex* spp., which grew in association with *Iris virginica shrevi* and *Dryopteris thelypteris pubescens.* The emergent plant zone of these ponds was dominated by *Scirpus acutus* and *Typha* spp. *Nuphar* and *Nymphaea* were abundant in the floating leaf zone. *Ranunculus flabellaris* commonly occurred where bottom sediments became exposed. Dominant submerged plants consisted of *Myriophyllum* sp. and *Potomogeton* spp. During 1985-86, *Zizania aquatica*, wild rice, extensively reduced the open water zone of Pond 35.

Comparative Effects of Abscisic Acid and Indole Acetic Acid on Phospholipid Bilayers. WILLIAM STILLWELL AND DANIEL BELCHER, Department of Biology, AND STEPHEN WASSALL, Department of Physics, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.——Both indole acetic acid (IAA) and abscisic acid (ABA) have been shown to enhance the permeability of phospholipid membranes to the nonelectrolyte erythritol and to the cation Pr^{3+}. Since these molecules are of similar size and have almost identical pKa's, it seems reasonable they effect membranes by similar mechanisms. The experiments reported here are an initial attempt to distinguish the effects of these two hormones on lipid bilayers. pH studies show that IAA is effective at enhancing bilayer permeability in both its dissociated and undissociated forms while ABA is ineffective as an anion. ABA enhances permeability only for mixed component bilayers, and is ineffective for membranes made of pure phosphatidylcholine (PC). IAA on the other hand greatly enhances permeability for pure PC membranes. We suggest ABA effects membranes at the interface between two different phospholipid types while IAA binds to the head group of PC enhancing permeability but not effecting the fatty acyl component.

Histochemical Observations of Embryogenesis in Suspension Cultures of *Asclepias tuberosa* (Asclepiadaceae). KATHRYN J. WILSON AND KERRY B. DUNBAR, Department of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.——Embryogenic *Asclepias tuberosa* suspension culture tissue was fixed, embedded in paraffin, sectioned, and stained with safranin and fast green. Stages of suspension culture embryogenesis are similar to those of zygotic embryogenesis. Pro-embryoids were observed as rapidly dividing cells surrounded by a thick common cell wall. The presence of three celled pro-embryoids in 7 day old suspension cell clumps suggests a single cell origin of embryoids. Globular, heart, torpedo, and mature embryoids also were observed in the suspension culture tissue. The earlier stages of embryogenesis were observed to have either thin suspensor-like structures or thick multicellular stalks. Month-old mature embryoids became disorganized and began to form a callus tissue. The disorganization of embryoids late in culture growth is a reason for selecting younger embryoids for regeneration experiments. Disorganized embryoid tissue may prevent embryoids from germinating normally.

The Variation of Four Bioclimatic Indexes in Indiana

Gary E. Dolph
Department of Botany
Indiana University at Kokomo
Kokomo, Indiana 46902

Introduction

The concepts of biotemperature and potential evapotranspiration ratio were introduced by Holdridge (13, 14) to allow the relationship between plant communities and bioclimate to be studied. Although Holdridge's life zone classification was initially developed to give a more accurate picture than existing systems (15, 19, 20) of the relationship between climate and vegetation in the tropics, its use can also be extended into the temperate region. By combining mean annual biotemperature, potential evapotranspiration ratio, total annual precipitation, and latitudinal position, over 100 life zones as well as over 600 transitional zones between these life zones may be identified. Although each of the life zones appears to have been named after a specific plant association, the classification developed in the life zone chart is really based on climate and not forest composition. However, each life zone theoretically supports a physiognomically distinct vegetation type whose geographic boundaries are closely defined by the boundaries of the climatically defined life zone. In the absence of climatic data, the life zone could still be mapped using vegetational physiognomy. Because the life zones are not defined on the basis of species composition, similar life zones may occur and may be mapped on different continents.

The concepts of warmth (as measured by effective temperature) and temperateness (as measured by equability) were introduced by Bailey in 1960. Bailey (2, 3) was not interested in developing an extensive bioclimatic classification such as Holdridge's classification (13, 14). Bailey was concerned that conventional measurements of temperature (namely, mean annual temperature and mean annual range in temperature) were too approximate to adequately define the thermal requirements of living and, in particular, fossil plants. Therefore, he developed two new thermal measurements, warmth and temperateness. Warmth was defined as the temperature characteristic of the beginning and end of a warm period during which vegetational growth occurred. Temperateness measures the perennial and/or seasonal freedom of any locality from extremes of heat or cold. Initially, Bailey (2) felt that variation in warmth had a much greater influence on the vegetation than variation in temperateness. Subsequent observations that the mixed mesophytic forests of eastern North America, of the Sierra Madre Oriental in Mexico, and of southeastern Asia are confined to areas of temperate climate ($M > 50$) and that shifts in population within the United States are toward areas of increasing temperateness (California, Arizona, New Mexico, and Florida) led Bailey (3) to conclude that temperateness is also an important bioclimatic element influencing the distribution of plants and animals. These concepts have been used extensively by Axelrod (1), who believes that changes in warmth and temperateness are the basis of floral evolution in the western United States.

Materials and Methods

The maps discussed in this paper were produced by analyzing two data bases, TEMPDAT (TEMPerature DATa) and PRECDAT (PRECipitation DATa), using the microcomputer program, CLIMATE (10). CLIMATE will allow a researcher to analyze seven different climatic variables at 91 different weather stations in Indiana and the surrounding States of Ohio, Kentucky, Illinois, and Michigan. The climatic parameters include mean temperature, total precipitation, mean range in temperature, mean biotemperature, potential evapotranspiration ratio, effective temperature, and equability. Each of these parameters may be studied over the whole year or over only a portion of the year, such as the growing season. For the purposes of this study, the growing season was defined as those months of the year which are free from frost. Depending on the location, the growing season runs from either April (in southern Indiana) or May (in northern Indiana) to October. Two maps are presented for each of the seven climatic variables: the first map illustrates the variation in a specific climatic variable for the whole year, and the second map illustrates the variation in that climatic variable during the growing season.

The data bases used in this analysis contain monthly means for temperature and precipitation for the period from 1941 to 1970. The data were obtained from the National Climatic Center in Asheville, North Carolina (21-25). Temperature data were available from 65 weather stations and precipitation data were available from 84 weather stations in Indiana. Because calculation of the potential evapotranspiration ratio requires both temperature and precipitation data, the nineteen weather stations for which precipitation data but not temperature data were available were not included in the analysis. In addition to the 65 weather stations utilized in Indiana, an additional 26 weather stations from the surrounding states of Ohio, Kentucky, Illinois, and Michigan were analyzed.

Temperature, Range in Temperature, and Precipitation

In order to understand the variation in biotemperature, potential evapotranspiration ratio, effective temperature, and equability, the variation in the climatic parameters from which these bioclimatic indexes are calculated, namely, temperature (Figure 1a-b), precipitation (Figure 1c-d), and range in temperature (Figure 2a-b), must be understood. Data are available in the literature on the variation in temperature, range in temperature, and precipitation in Indiana, but the maps presented illustrate the variation of these climatic parameters in the English and not the metric system (4, 17, 26). The maps presented in this paper show the variation in temperature, range in temperature, and precipitation in the metric system. These maps compare quite favorably with those prepared by other authors (4, 17, 26).

The mean annual temperature (Figure 1a) increases from lows of less than 10 °C in northern Indiana to highs in excess of 13 °C in southern Indiana. The tendency is for temperature to increase in a slightly northeast to southwest direction. During the growing season (Figure 1b), the mean temperature increases from lows of less than 18 °C along southern Lake Michigan to highs of more than 20° in southern Indiana. In general, west-central and southern Indiana have a mean temperature during the growing season of more than 19 °C, whereas east-central and northern Indiana have a mean temperature during the growing season of less than 19 °C.

Total annual precipitation also increases from north to south (Figure 1c). The total annual precipitation increases from lows of less than 90 cm/yr in northern Indiana to highs in excess of 110 cm/yr in southern Indiana. The gradual increase in precipitation from northern to southern Indiana is interrupted by a local high in north-central Indiana reflecting increased precipitation to the southeast of Lake Michigan. In this area, the total annual precipitation exceeds 95 cm/yr, and local highs can exceed 120 cm/yr. During the growing season (Figure 1d), the precipitation is lowest in northern and extreme eastern Indiana. In this region, the average summer precipitation is less than 55 cm. In central and southern Indiana, the precipitation during the growing season increases toward the southwest from lows of less than 55 cm to highs in excess of 65 cm. Locally, the precipitation during the growing season around southern Lake Michigan exceeds 60 cm.

The mean annual range in temperature decreases from the northwest to the southeast

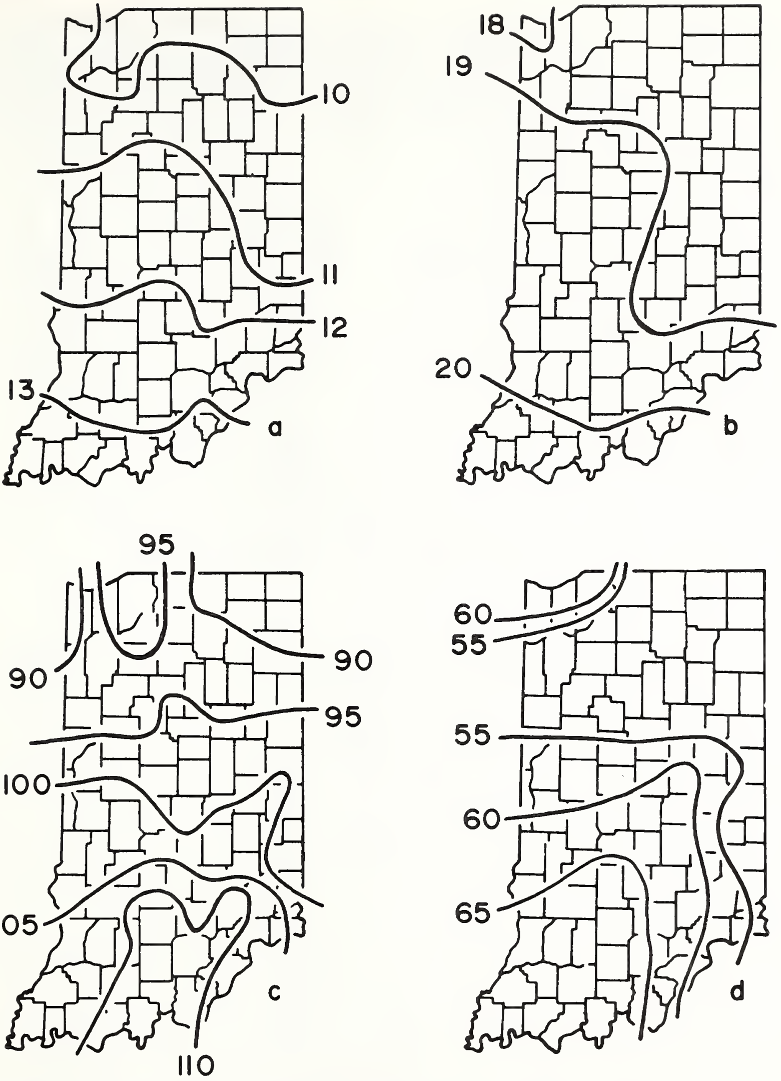


FIGURE 1. Variation in mean annual temperature (a), mean temperature during the growing season (b), total annual precipitation (c), and total precipitation during the growing season (d) in the counties of Indiana.

(Figure 2a) from differences of more than 27 °C in northwestern Indiana to differences of less than 25 °C in southeastern Indiana. The difference is also less than 27 °C in the immediate vicinity of Lake Michigan. In contrast, the mean range in temperature during the growing season (Figure 2b) is highest in south-central Indiana, where the difference exceeds 12 °C, and lowest in northern and southern Indiana, where the difference is less than 11 °C in northern Indiana and less than 12 °C in southern Indiana.

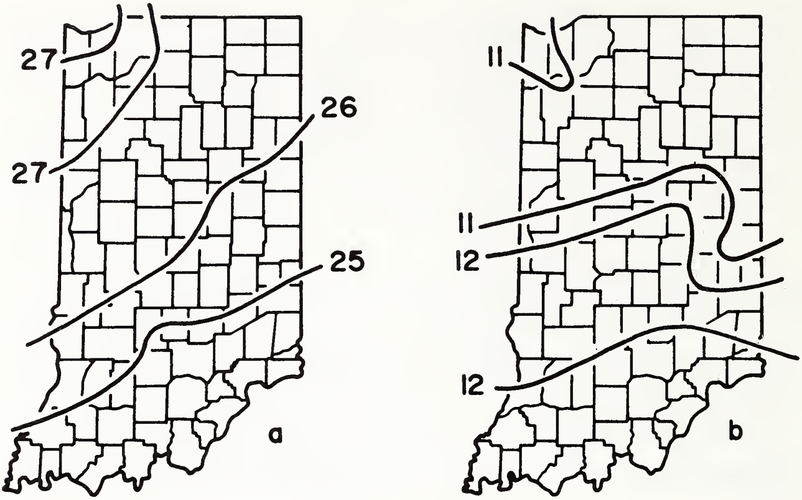


FIGURE 2. Variation in mean annual range in temperature (a) and mean range in temperature during the growing season (b) in the counties of Indiana.

Biotemperature and Potential Evapotranspiration Ratio

Unlike temperature, biotemperature measures only the heat which affects plant growth. The mean annual biotemperature (13, 14) is defined as the mean of all unit-period temperatures having an average temperature of more than 0 °C and less than 30 °C. If the mean temperature for a month is less than 0 °C or more than 30 °C, then the mean temperature for that month is not added to the total of mean monthly temperatures. Zero is added instead. Temperatures of less than 0 °C or more than 30 °C do not physiologically affect the vegetation. The vegetation merely remains dormant until more favorable conditions return. When temperatures are below 0 °C, the plants lose their leaves, and no growth takes place. At temperatures over 30 °C, the plants also become dormant to prevent respirational losses of photosynthate and to limit water stress.

Moving from the equator to the poles, Holdridge (13, 14) defined seven latitudinal regions based on mean annual biotemperature: tropical (> 24 °C), subtropical (∿18 °C to 24 °C), warm temperate (12 °C to ∿18 °C), cool temperate (6 °C to 12 °C), boreal (3 °C to 6 °C), subpolar (3 °C to 1.5 °C), and polar (< 1.5 °C). In any single latitudinal region, up to six altitudinal belts may also be recognized based on mean annual biotemperature: premontane (∿18 °C to 24 °C), lower montane (12 °C to ∿18 °C), montane (6 °C to 12 °C), subalpine (3 °C to 6 °C), alpine (1.5 °C to 3°C), and nival (< 1.5 °C). All six altitudinal belts are present in the tropical latitudinal region, but the number of altitudinal belts decreases in latitudinal regions closer to the poles, because the lower, warmer altitudinal belts are not represented.

The value of the mean annual biotemperature which separates the subtropical from the warm temperate latitudinal region and the premontane from the lower montane altitudinal belt is not fixed at 18 °C (see above). The actual value of the mean annual biotemperature separating these life zones can vary from 16 °C to 18 °C. The value is an approximation of the mean annual biotemperature at which temperature-sensitive tropical plants can no longer live within a forest.

The mean annual biotemperature increases from north to south in Indiana. The mean annual biotemperature increases from lows of less than 11 °C in northern Indiana to highs of more than 13 °C in southern Indiana (Figure 3a). In northern Indiana, the weather stations all record subfreezing temperatures for at least a portion of the winter. In southern Indiana, subfreezing temperatures may occur on some days of the year, but

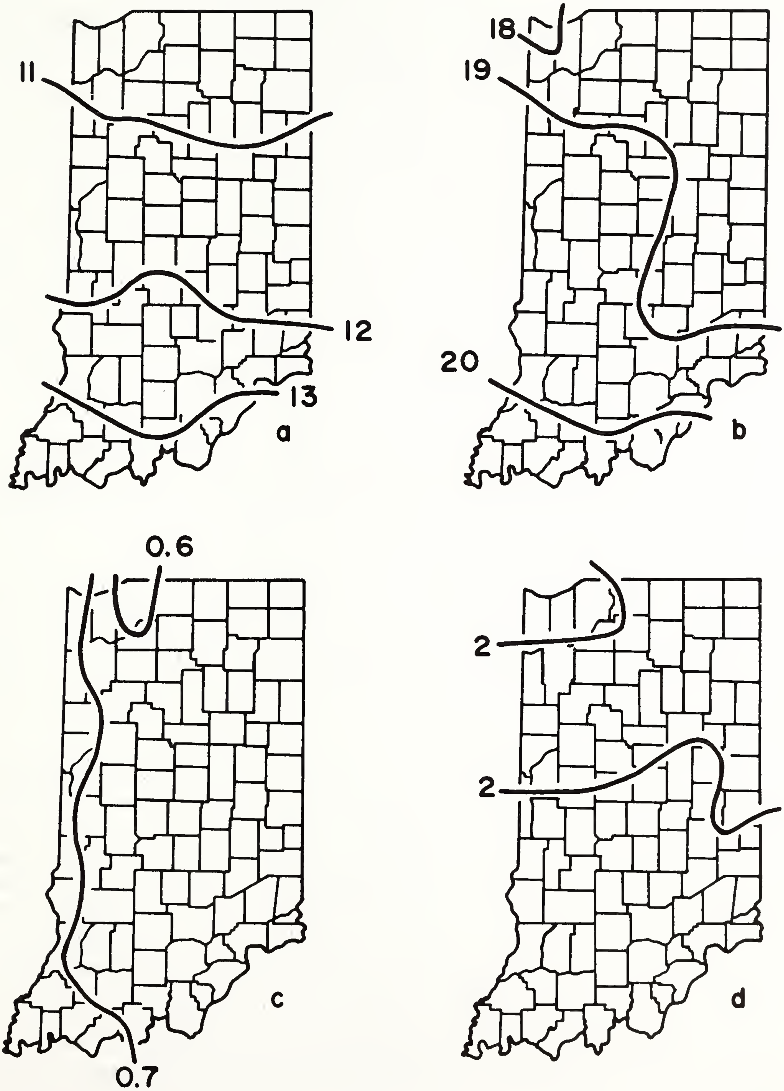


FIGURE 3. Variation in mean annual biotemperature (a), mean biotemperature during the growing season (b), potential evapotranspiration ratio (c), and potential evapotranspiration ratio during the growing season (d) in the counties of Indiana.

the monthly average temperatures rarely fall below freezing. In no county in Indiana does the monthly average temperature rise above 30 °C. As a result, the mean annual biotemperature in southern Indiana closely parallels the variation in mean annual temperature. Only in northern Indiana, where some months of the year average less than 0 °C, is there a significant variation in the maps for mean annual biotemperature and mean annual temperature. The mean annual biotemperature tends to be higher in northern Indiana, because the means of the months having subfreezing temperatures are not subtracted from the total of mean monthly temperatures. Values for mean annual biotemperature place northern and central Indiana in the cool temperate latitudinal region and southern Indiana in the warm temperate latitudinal region.

A comparison of Figure 1b with Figure 3b indicates that the variation in temperature and biotemperature during the growing season is identical. The maps are identical because monthly mean temperatures below 0 °C and above 30 °C do not occur during the growing season in Indiana. Therefore, the calculated means for both variables are the same at all weather stations. During the growing season, the mean biotemperature in Indiana is as high as the mean annual biotemperature in the subtropical latitudinal region.

The potential evapotranspiration ratio is a comparison between the amount of water lost in a life zone by the processes of evaporation and transpiration (the potential evapotranspiration) and the amount of water gained in a life zone as measured by the total precipitation. Potential evapotranspiration is calculated by multiplying the mean biotemperature by 58.93. The potential evapotranspiration ratio (PER) is calculated using the following equation (13, 14):

$$PER = (58.93 \times T^{BIO})/P,$$

where the potential evapotranspiration ratio is a dimensionless number, T^{BIO} is the average biotemperature in °C over the time period under study, and P is the average precipitation in mm over the same time period. Ideally, total annual precipitation should balance potential evapotranspiration, resulting in a potential evapotranspiration ratio of 1.0 or unity. If potential evapotranspiration is greater than the total annual precipitation, the potential evapotranspiration ratio is greater than unity, the total annual precipitation is less than is needed to balance the water lost through evaporation and transpiration, and the climate becomes more arid. If potential evapotranspiration is less than the total annual precipitation, the potential evapotranspiration ratio is less than unity, the total annual precipitation is more than is needed to balance the water lost through evaporation and transpiration, and the climate becomes more humid.

The life zones which have similar humidity conditions, as measured by the potential evapotranspiration ratio, can be grouped into the same humidity province. Holdridge (13, 14) recognized twelve humidity provinces based on the potential evapotranspiration ratio: semiparched (64.0 to 32.0), superarid (32.0 to 16.0), perarid (16.0 to 8.0), arid (8.0 to 4.0), semiarid (4.0 to 2.0), subhumid (2.0 to 1.0), humid (1.0 to 0.5), perhumid (0.5 to 0.25), superhumid (0.25 to 0.125), semisaturated (0.125 to 0.0625), subsaturated (0.0625 to 0.03125), and saturated (< 0.03125). The most favorable humidity provinces for plant growth and animal activity cluster around a potential evapotranspiration ration of 1.0 and include the subhumid (1.0 to 2.0) and humid (0.5 to 1.0) humidity provinces. With respect to human activity, the choice of life zone tends toward the drier life zones of the subhumid humidity province as temperature increases.

The potential evapotranspiration ratio decreases from highs in excess of 0.7 in western Indiana and to lows of less than 0.7 in eastern and central Indiana (Figure 3c). Because the area southwest of Lake Michigan receives an unusually high amount of precipitation (Figure 1c), this area also has an unusually low potential evapotranspiration ratio. More precipitation falls in Indiana during the year than is needed to balance potential evapotranspiration, and the potential evapotranspiration ratio is less than unity. Indiana is located in the humid (PER between 0.5 and 1.0) humidity province. The humid humidity province is one of the two most favorable provinces for plant growth, accounting at least in part for Indiana's impressive agricultural output.

During the growing season (Figure 3d), the potential evapotranspiration ratio is highest in northern Indiana with highs in excess of 2.0 and lowest around Lake Michigan and in central and southern Indiana with lows of less than 2.0. Less precipitation falls in Indiana during the growing season than during the remainder of the year. The precipitation is less than is required to balance the water lost through evaporation and transpiration, and the potential evapotranspiration ratio is higher during the growing season than during the whole year. During the growing season, the values of the potential evapotranspiration ratio in Indiana are as high as the annual values in the semiarid (PER > 2.0) to subhumid (PER between 1.0 and 2.0) humidity provinces.

Warmth and Temperateness

Bailey (2, 3) did not feel that mean annual temperature and mean annual range in temperature effectively described the thermal regimes under which plants and animals exist. Therefore, he defined two new indexes to quantify the warmth and temperateness of any locality. These indexes are effective temperature and equability. Effective temperature is a measure of warmth. Equability is a measure of temperateness. Graphically, effective temperature is represented as a series of rays and equability as a series of concentric circles superimposed on a normal Cartesian coordinate system having mean annual temperature as the abscissa and mean annual range in temperature as the ordinate (a nomogram, Figure 5b).

The temperature characteristic of the beginning and end of a warm period during which vegetational growth prospers is a measure of the warmth of that locality. This time period will be largely free from frost. One measure of warmth is effective temperature (1, 2):

$$ET = (8T + 14A)/(8 + A),$$

where ET is the effective temperature in °C, T is the mean temperature in °C for the time period under study, and A is the range in temperature in °C for the same time period. The change from polar to tropical climates is indicated by increasing values of effective temperature from 0 °C in polar climates to 30 °C in tropical climates. Standard temperature designations, such as cold and warm temperate, subtropical, and tropical, cannot be applied to values of effective temperature. Instead, Bailey (2) recognized three major climatic zones based on relative warmth: low latitude climates (ET > 18.0 °C), midlatitude climates (ET between 10.0 °C and 18.0 °C), and high latitude and altitude climates (ET < 10.0 °C). Each of these major climatic zones was further subdivided into a number of minor climatic categories. The low latitude climates were subdivided into torrid (ET > 24.1 °C), hot (ET between 20.8 °C and 24.1 °C), and very warm (ET between 18.0 °C and 20.8 °C) climates; the midlatitude climates were subdivided into warm (ET between 15.5 °C and 18.0 °C), mild (ET between 13.4 °C and 15.5 °C), cool (ET between 11.6 °C and 13.4 °C), and very cool (ET between 10.0 °C and 11.6 °C) climates; and the high latitude and altitude climates were subdivided into cold (ET between 8.6 °C and 10.0 °C), very cold (ET between 7.5 °C and 8.6 °C), and glacial (ET < 7.5 °C) climates. Drought and continentality do not affect the calculation of effective temperature, although altitude will modify the results. Therefore, isotherms for effective temperature tend to extend from coast to coast except where lower effective temperatures are deflected toward the equator by high mountains.

The variation in mean annual effective temperature in Indiana (Figure 4a) has a total magnitude of less than one degree. The mean annual effective temperature increases from lows of less than 13.4 °C in northern and central Indiana to highs of slightly more

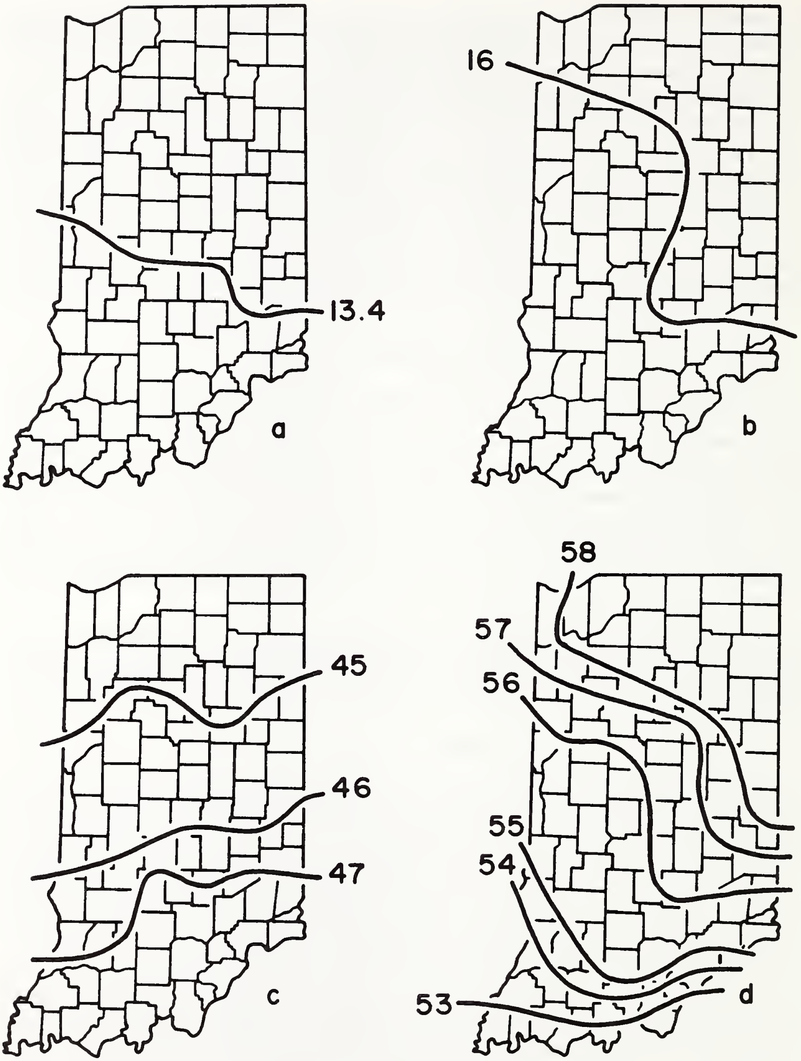


FIGURE 4. Variation in effective temperature (a), effective temperature during the growing season (b), equability (c), and equability during the growing season (d) in the counties of Indiana.

than 13.4°C in southern Indiana. An isotherm of 13.4°C was mapped, because this isotherm represents the dividing line between cool midlatitude climates (ET < 13.4°C) and mild midlatitude climates (ET > 13.4°C). Northern Indiana has a cool midlatitude climate, and southern Indiana has a mild midlatitude climate. Bailey (2) also divided the climate of Indiana into a northern, cool and a southern, mild midlatitude climate, although he could not place the boundary with precision due to the small scale of his map.

During the growing season in Indiana (Figure 4b), the effective temperature decreases from northeast to southwest from lows of less than 16 °C in northern and east-central Indiana to highs of more than 16 °C in southern and west-central Indiana. During the growing season, a warm midlatitude climate (ET between 15.5 °C and 18.0 °C) exists in Indiana. The values for effective temperature do not fall below 15.5 °C during the growing season, and, therefore, this major isothermal boundary cannot be mapped.

Temperateness, as recorded by equability, measures the freedom of a specific locality from extremes of heat and cold regardless of whether these extremes are seasonal (measured by mean annual range in temperature) or perennial (measured by mean annual temperature) in occurrence. The equability at a specific weather station is calculated as follows (1, 3):

$$M = 109.0 - 30 \log((T - 14)^2 + (1.46 + 0.366A)^2),$$

where M is the equability, a dimensionless index ranging from 0 to 100, T is the average temperature in °C for a specific time period, and A is the range in temperature in °C for the same time period. A climate which is totally free from extremes of heat and cold has an equability of 100 and a mean annual temperature of 14.0 °C. The greater the seasonal fluctuation in temperature, as measured by the mean annual range in temperature, and/or the greater the departure of the mean annual temperature at a site from the ideal mean of 14.0° C, the lower the calculated equability becomes.

Bailey (3) defined two different climatic orders based on temperateness: temperate climates ($M > 50$) and intemperate climates ($M < 50$). Each of these climatic orders was subdivided into three climatic classes. The temperate climatic order was subdivided into the supertemperate ($M > 80$), very temperate (M between 80 and 65), and temperate (M between 65 and 50) climatic classes; and the intemperate climatic order was subdivided into the subtemperate (M between 50 and 35), intemperate (M between 35 and 20), and extreme ($M < 20$) climatic classes. A two-layered classification was adopted to allow plotting of temperateness on maps of different scales. This classification (3) completely revised an earlier classification of temperate climates (2) by introducing the temperate and intemperate climatic orders, by changing the name of the most temperate class from constant to supertemperate, by reducing the lower limit of each temperateness class by M 5, and by modifying the original equations used to calculate equability.

Annual equability increases from north to south from lows of less than M 45 in northern Indiana to highs of more than M 47 in southern Indiana (Figure 4c). The mean annual temperature is approaching 14.0 °C in southern Indiana (Figure 1a), and the mean annual range in temperature is lowest in southern Indiana (Figure 2a). Changes which cause the mean annual temperature to become closer to the ideal value of 14.0 °C and which reduce the mean annual range in temperature will also cause the climate to become more temperate (the value of M increases). Therefore, southern Indiana has a more equable climate (a higher value of M) than northern Indiana. Based on equability, Indiana has a subtemperate (M between 50 and 35) climate. These results substantiate Bailey's claim (3) that the northeastern United States, including Indiana, have an intemperate ($M < 50$) and not a temperate climate. Equability measures extremes of heat and/or cold. The bioclimate of Indiana is rated as intemperate, because of the extreme cold waves that cross the State during winter.

The equability during the growing season in Indiana decreases from highs in excess of M 58 in northeastern Indiana to lows of less than M 53 in southwestern Indiana (Figure 4d). No other temperature index decreases toward the south in Indiana. The mean temperature during the growing season in southern Indiana is becoming increasingly greater than the ideal mean of 14.0 °C (Figure 1b), and the mean range in temperature during the growing season is greater in south-central Indiana than in northern Indiana (Figure 2b). Changes which cause the mean temperature to depart more radically from the ideal mean of 14.0 °C and which increase the mean range in temperature will cause the climate to become less temperate (the value of M decreases). Therefore, southern Indiana has a less temperate climate during the growing season (a lower value of M) than northern Indiana. During the growing season, Indiana does have a temperate (M between 50 and 65) climate.

Conclusions

Based on the life zone classification system of Holdridge (13, 14), northern and central Indiana are in the cool temperate moist forest life zone and southern Indiana is in the warm temperate moist forest life zone (Figure 5a). The intervening area is a zone of climatic transition. The cool temperate moist forest life zone terminates as the warm-wet transition of the cool temperate moist forest life zone; and the warm temperate moist forest life zone starts as the cool transition of the warm temperate moist forest life zone. These conclusions are similar to those reached by Sawyer and Lindsey (16) in their general study of the bioclimatic formations east of the 102 W meridian in the United States, except that the area representing warm temperate montane moist forest in their paper is considered a transitional climatic zone between the cool temperate and warm temperate moist forests in this paper.

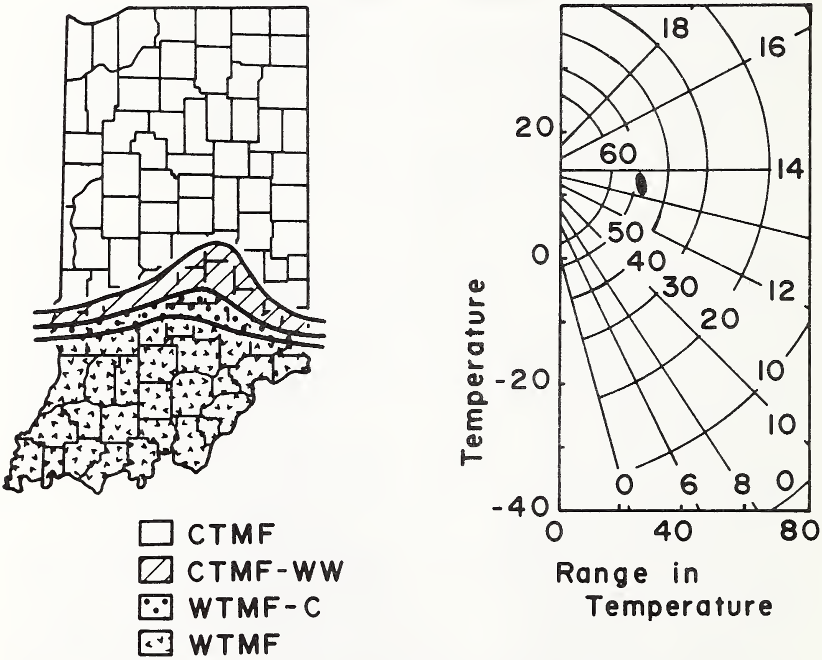


FIGURE 5. The bioclimatic formations of Indiana derived by application of Holdridge's system (a, on the left), and the nomogram of thermal data for Indiana derived by the application of Bailey's system (b, on the right).

Holdridge (14) makes two important points about transition zones and the two life zones adjacent to them. First, the transition zone should be very narrow. The transition zone is very narrow in Indiana, and it is confined to the south-central portion of the State. Second, the plant associations in the life zones on either side of the transition zone should have distinctly different physiognomies. Although a large number of floristic and synecological studies have been published dealing with the vegetation of Indiana, few physiognomic analyses have been carried out.

The only large-scale physiognomic study that has been carried out in Indiana attempted to relate the variation in leaf margin type of the woody, dicotyledonous plant species with bioclimate (9, 11). Initially, the variation in the percentage of woody, dicotyledonous plant species having leaves with entire margins seemed more closely related to edaphic conditions influencing the distribution of the woody, dicotyledonous shrub and vine species than to the influence of any major climatic parameter, such as temperature or precipitation (9). In the counties of northern Indiana, the percentage of woody, dicotyledonous plant species having leaves with entire margins is as high (> 20%) as the percentage in southern Indiana. Edaphic conditions certainly exert a controlling influence on species distribution and indirectly on foliar physiognomy in northern Indiana. One of the chief physiographic features that distinguishes northern from central and southern Indiana is the large number of lakes and bogs covering the area (18). A number of tree (e.g., *Betula lutea*, *Quercus ellipsoidalis*, or *Salix amygdaloides*), shrub (e.g., *Betula pumila*, *Cornus rugosa*, or *Sambucus pubens*), and vine (e.g., *Parthenocissus vitacea*) species extend into northern Indiana from Michigan and western Ohio only because the appropriate edaphic conditions are available. The southernmost distributional boundary of these species is not the transition zone between the cool temperate and warm temperate moist forest life zones. Their distributional boundary is the southern limit of the Northern Moraine and Lake Region. However, the high percentage of woody dicotyledonous plant species having leaves with entire margins in northern Indiana does not indicate that the cool temperate and warm temperate moist forest life zones do not have distinct physiognomies. The flora of northern Indiana represents an edaphic association and not the climatic or zonal association characteristic of the cool temperate moist forest life zone.

The percentage of woody, dicotyledonous plant species having leaves with entire margins in the counties corresponding to the warm temperate moist forest life zone is greater (> 20%) than the percentage of woody, dicotyledonous plant species having leaves with entire margins (< 15%) in the adjacent counties found in the cool temperate moist forest life zone. The change in foliar physiognomy occurs within the transition zone. The transition zone between the cool temperate and warm temperate moist forest life zones does accurately delimit the northernmost boundary to which many southern species extend. The trees, shrubs, and vines reaching the northern limit of their distribution in southern Indiana include *Aesculus octandra*, *Oxydendrum arboreum*, *Tilia heterophylla*, *Forestiera acuminata*, *Rubus odoratus*, *Viburnum molle*, *Anisostichus capreolata*, and *Calycocarpum Lyoni*.

The simplest explanation for these patterns is that the foliar physiognomy of northern Indiana is edaphically controlled while the foliar physiognomy of southern Indiana is climatically controlled. However, a number of shrub (e.g., *Gaylussacia baccata* and *Vaccinium vacillans*) and vine (e.g., *Lonicera dioica* and *L. prolifera*) species, whose distributions are edaphically controlled, occur in both northern and southern Indiana. Because these species have leaves with entire margins, they also exert a significant influence on the foliar physiognomy of northern and southern Indiana. The physiognomic difference between the cool temperate and warm temperate moist forest life zones does reflect a climatically controlled floristic difference, but the final percentage is modified somewhat by the presence of species whose distribution in both northern and southern Indiana is edaphically and not climatologically controlled.

Application of the concepts of warmth and temperateness developed by Bailey (2,

3) to the climate of Indiana (Figures 4a-d and 5b) substantiate the conclusions reached using the Holdridge system of life zone classification. The 13.4 °C isotherm for effective temperature divides Indiana into two parts: a northern and central portion having a cool midlatitude climate and a southern portion having a mild midlatitude climate. The 13.4 °C isotherm for effective temperature falls in approximately the same position as the transition zone identified using Holdridge's life zone classification (Figure 5a). The shift from a warm midlatitude climate to a cool midlatitude climate at an effective temperature of 13.4 °C effectively delimits the northernmost distributional boundary of the woody, dicotyledonous plants which enter Indiana from the south as well as a major change in foliar physiognomy (see above).

Although a correlation between foliar physiognomy and the variation in warmth and equability has been intimated (1), no detailed analysis of the relationship between these variables has been carried out. Studies of the percentage of species having large leaves ($>$ 20.25 sq cm *sensu* 5) in the tropical lowlands of the Western Hemisphere and in Indiana indicate that the two areas have a similar foliar physiognomy with respect to leaf size. The average percentage of species having large leaves is 83.7% in Indiana (6, 8, 27) and 83.0% in the tropical lowlands of the Western Hemisphere (7). The similarity can be explained by examining the variation in warmth and equability in Indiana.

The effective temperature in Indiana averages 13.4 °C/yr. During the growing season, the effective temperature increases to 16.1 °C. The increase in effective temperature is equivalent to a change from a cool to mild midlatitude climate to a warm midlatitude climate during the growing season. Based on equability (Figure 4c), the annual climate of Indiana is intemperate ($M < 50$), but only marginally so. During the growing season, the climate of Indiana becomes distinctly temperate ($M > 50$, Figure 4d). During the growing season, the position of Indiana on the nomogram shifts upwards towards greater warmth and to the left towards greater equability. In other words, the climate becomes more tropical and less temperate in nature. Givnish (12) predicted that average leaf size in warm temperate and tropical forests should be approximately equal. Because the plants are only photosynthetically active during the growing season in Indiana, the plants respond to the higher than average warmth and greater equability of the climate by producing leaves which are as large on the average as those in the tropics. Winter has no influence on leaf size, because no leaves are present in the winter.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. SER 8004789. The author would like to express his thanks to Drs. Arthur C. Gentile and David L. Dilcher for critically reviewing this manuscript.

Literature Cited

1. Axelrod, D.I. and H.P. Bailey. 1969. Paleotemperature analysis of Tertiary floras. Palaeogeogr., Palaeoclim., Palaeoecol. 6: 163-195.
2. Bailey, H.P. 1960. A method of determining warmth and temperateness of climate. Geograf. Ann. 42: 1-16.
3. ____. 1964. Toward a unified concept of temperate climate. Geograph. Rev. 54: 516-545.
4. Clark, G.D. and D. Larrison. 1980. The Indiana water resource: Availability, uses, and needs. Indiana Department of Natural Resources, Indianapolis, Indiana, 508 pp.
5. Dilcher, D.L. 1973. The Eocene floras of southeastern North America. In: A. Graham (Ed.), *Vegetation and Vegetational History of Northern Latin America*, pp. 39-59, Elsevier, New York, 393 pp.
6. Dolph, G.E. 1971. A comparison of local and regional leaf characteristics in Indiana. Proc. Indiana Acad. Sci. 80: 99-103.

7. ____. 1978. Variation in leaf size and margin type with respect to climate. Cour. Forsch.-Inst. Senckenberg 30: 153-158.
8. ____. 1979. Leaf size variation at Cook's woods. Proc. Indiana Acad. Sci. 88: 77-82.
9. ____. 1984. Leaf form of the woody plants of Indiana as related to environment. In: N.S. Margaris, M. Arianoustou-Farragitaki, and W.C. Oechel (Eds.), *Being Alive on Land*, pp. 51-61, Tasks for Vegetation Science, Dr. W. Junk Publishers, The Hague, 322 pp.
10. ____. 1985. CLIMATE: A microcomputer program allowing student preparation of climatic maps for Indiana. Proc. Indiana Acad. Sci. 94: 489-498.
11. ____. 1986 LEAF MARGIN, A computer simulation of leaf margin variation in Indiana. Proc. Indiana Acad. Sci. 95: 469-477.
12. Givnish, T.J. 1976. Leaf form in relation to environment: A theoretical study. Ph.D. Thesis, Princeton Univ., 467 pp.
13. Holdridge, L.R. 1967. Life zone ecology. Tropical Science Center, San Jose, Costa Rica, 206 pp.
14. ____, W.C. Grenke, W.H. Hatheway, T. Liang, and J.A. Tosi, Jr. 1971. Forest environments in tropical life zones: A pilot study. Pergamon, New York, 747 pp.
15. Köppen, W. and R. Geiger. Handbuch der Climatologie. Teil I D, Borntraeger, Berlin.
16. Sawyer, J.O., Jr. and A.A. Lindsey. 1964. The Holdridge bioclimatic formations of the eastern and central United States. Proc. Indiana Acad. Sci. 73: 105-112.
17. Schaal, L.A. 1966. Climate. In: A.A. Lindsey (Ed.), *Natural Features of Indiana*, pp. 156-170, Indiana Academy of Science, Indianapolis, Indiana, 597 pp.
18. Schneider, A.F. 1966. Physiography. In: A.A. Lindsey (Ed.), *Natural Features of Indiana*, pp. 40-56, Indiana Academy of Science, Indianapolis, Indiana, 597 pp.
19. Thornthwaite, C.W. 1931. The climates of North America according to a new classification. Geograph. Rev. 21(4): 633-655.
20. ____. 1948. An approach to a rational classification of climate. Geograph. Rev. 38(1): 55-94.
21. U.S. Department of Commerce Environmental Data Service. 1973a. Climatology of the United States, No. 81 (Illinois). Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-1970. Asheville, North Carolina.
22. ____. 1973b. Climatology of the United States, No. 81 (Indiana). Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-1970. Asheville, North Carolina.
23. ____. 1973c. Climatology of the United States, No. 81 (Kentucky). Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-1970. Asheville, North Carolina.
24. ____. 1973d. Climatology of the United States, No. 81 (Michigan). Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-1970. Asheville, North Carolina.
25. ____. 1973e. Climatology of the United States, No. 81 (Ohio). Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-1970. Asheville, North Carolina.
26. Visher, S.S. 1944. Climate of Indiana. Indiana University, Bloomington, 511 pp.
27. Withrow, A.P. 1932. Life forms and leaf size classes of certain plant communities of the Cincinnati region. Ecology 13: 12-35.

Cell and Tissue Development in One and Two Year Old Culms of *Arundo donax L.*

Jerry J. Nisbet and Marilyn Sue Veselack
Department of Biology
Ball State University, Muncie, Indiana 47306

Previous *Arundo donax* research investigated clarinet reeds selected by professional clarinetists from the woodwind reed market. Cell and tissue characteristics compared between usable and non-usable reeds showed the eight significantly important characteristics were growth related while one was directly related to position within the culm internode.

One year old Arundo culms were collected from growth bins of Christy Woods Greenhouse at Ball State University. Culm sections, measuring approximately one inch, were cut, treated, and processed for sectioning and examination. The material contained thin walled cells and tissues of young plant material. Secondary walls were absent from parenchyma cells and tissues. Fiber cells and vascular bundle tissues were at an early stage of growth development. Meristematic cells were abundant.

Two year old California grown Arundo culms that had been harvested and cured in preparation for the manufacture of clarinet reeds were marked with identifying codes and processed for sectioning. Cross section pieces were removed from each internode at three locations and labeled as to culm position, culm quadrant, and culm internode. Culm positions were: (a) bud end of the internode, (b) middle of the internode, and (c) directly below the bud area of the upper internode. Culm quadrants were: (1) the quarter of stem with bud origination centered, (2) ninety degrees clockwise from quadrant one, (3) one hundred eighty degrees clockwise from quadrant one, and (4) two hundred seventy degrees clockwise from one. Culm internodes were numbered starting from the ground (one) and progressing up the culm in numerical sequence to the plume.

Example identifying code: 4 C II 6 a 3 (4 = culm; C = California Arundo; II = number of growth years; 6 = internode; a = culm position within internode; 3 = quadrant within internode).

Microscope slides of selected cross sections were prepared with chemical treatment, embedded in paraplast for sectioning, microscopically examined, and photographed. Information found was compared with the results of prior Arundo studies of material submitted by professional clarinetists. A list of comparative results follows as listed:

Meristematic Cells/Tissues

California Arundo (2 year) — meristematic cells found: in areas from center culm edge towards center; within the middle area of the culm walls; and next to epidermis and toward center of the culm walls.

Clarinet Reed Arundo — no meristematic cells founds.

Cell and Tissue Growth Development

California Arundo (2 year) — parenchyma: uneven sizes and unsymmetrical; absence of secondary walls and intercellular spaces within parenchyma; thin fiber cell walls and incomplete fiber rings around vascular bundles; thin walled cells between the band of fiber and epidermis; and irregular thicknesses in the band of fiber.

Clarinet Reed Arundo — parenchyma: uniform and symmetrical; secondary walls and intercellular spaces within parenchyma; thick and well formed fiber cell walls within fiber ring surrounding vascular bundles; thick walled cells between the band of fiber and epidermis; and regularity of thicknesses in the band of fiber.

Irregularity of Cell Size/Placement

California Arundo (2 years) — stress movement shown in parenchyma by atypical cell shapes suggesting a flow of uneven tensions within the culm; large, thin walled parenchyma interpersed with one row of smaller and thicker walled parenchyma between epidermis and the band of fiber; incompletely formed fiber ring around vascular bundles; and mitosis of vascular bundles throughout culm.

Clarinet Reed Arundo — typical cell shapes without stress deformities; cells are approximately equal in size in the area between epidermis and the band of fiber, with at least two rows of small thick walled cells next to the epidermis; vascular bundles with completely formed fiber rings; and no mitosis of vascular bundles.

Conclusions and Recommendations

1. Clarinet reed blanks should be cut from the Arundo culm with the blade tip oriented toward the center (position b).
2. Clarinet reed blanks cut from position (c), quadrant 3 contain undesirable cell and tissue formation — gnarling and twisting of vascular bundles as well as irregular growth patterns in cells/tissues.
3. The incompleteness in growth development as indicated by the internal cell and tissue structures of two year old California Arundo implies an acceleration of disintegration of the material which suggests unstableness as well as a short period of usefulness for use as clarinet reeds.

Appreciation is extended to the Indiana Academy of Science for partial funding of laboratory assistance for the study and to Rico Import Company for providing culms of Arundo and partial funding to process the culms.

A Compilation of Plant Diseases and Disorders in Indiana - 1986

GAIL E. RUHL, DONALD H. SCOTT, RICHARD X. LATIN AND PAUL C. PECKNOLD
Department of Botany and Plant Pathology
Purdue University
West Lafayette, Indiana 47907

Introduction

The Plant Diagnostic Clinic in the Department of Botany and Plant Pathology at Purdue University is a service of the Cooperative Extension Service, Purdue Agricultural Experiment Station. Plant disease diagnosis and weed identification are gratuitous services offered by the clinic. Of the 1300 specimens received annually, approximately 85% are submitted by county extension agents. The remainder of samples come directly from commercial growers, homeowners, private consultants and other interested persons. This paper is a summary of the major plant diseases and disorders which were diagnosed in the clinic and observed throughout the state in 1986.

Methods

Plant specimens are submitted to the Plant Diagnostic Clinic from county extension agents, homeowners, growers, nursery operators, consultants, and others. Specimens are diagnosed visually or by culturing the pathogen on selected media. Some virus diseases are diagnosed by the leaf dip (negative stain) technique utilizing the electron microscope. Once a disease or disorder is diagnosed, appropriate control measures are suggested. A summary of the samples diagnosed from January 1 through November 26, 1986 is given in Table 1.

Results

The incidence and severity of infectious diseases were greatly influenced by extremes in environmental conditions in 1986. Severe hard freezes in April caused extensive injury to the new growth of many woody ornamentals. Frequent rainfall in late May and early June resulted in a high incidence of various fungal leafspot diseases. Drought conditions in July and August resulted in widespread site-related problems. Whitening of leaves due to drift of the herbicide 'Command' onto vegetables, ornamentals, shade and fruit trees, and other vegetation caused numerous complaints.

Shade and Ornamental Trees

Diseases: As in previous years (1,2,3,4,5,6,7) leaf and petiole anthracnose was common on ash, sycamore, oak and maple. Sycamores experienced extensive leaf drop in late spring due to anthracnose infection of the petioles. Severe defoliation was also common on hard maples (especially Norway) in late summer due to petiole and leaf infection. Apple scab on crabapples was severe by mid-summer. Actinopelte leaf spot of pin oak was widespread by late summer. Diplodia tip blight on Austrian and Red pine as well as Verticillium wilt on redbud, smoke tree and maple were diagnosed.

Disorders: Severe hard freezes in April caused extensive injury to the new growth of many trees; especially the honeylocust and ginko. Iron chlorosis of pin oak (in conjunction with Actinopelte leaf spot) was very prevalent in late summer, in part due to the extended dry periods which occurred at this time.

Ornamentals

Diseases: Juniper twig blight (both *Kabatina* and *Phomopsis*) was evident during early spring, as were cedar apple, cedar hawthorn and cedar quince rust. Powdery mildew

TABLE 1. Plant samples received in the Purdue Plant Diagnostic Clinic Jan. 1 through Nov. 26, 1986.

Plant Specimen	Number of Samples	Diseases[1]	Disorders[2]	Chem.[3]	Nutr.[4]	Insect[5]	Other[6]
AGRONOMIC							
Corn	92	34	32	18	8	9	11
Soybeans	94	59	9	26	1	1	14
Small Grain	67	59	13	1	1	0	11
Forage Grasses and Legumes	25	16	2	1	4	3	4
ORNAMENTAL							
Trees-Shade and Ornamental	329	105	159	20	16	51	47
Shrubs and Groundcover	111	29	42	7	2	10	26
Flowers	76	29	42	7	2	9	18
House plants	16	4	6	0	1	3	3
FRUIT							
Tree Fruit	85	30	26	5	2	11	11
Small Fruit	64	29	20	2	1	3	9
VEGETABLE	70	28	9	11	5	3	26
TURFGRASS	57	34	11	0	0	0	16
PLANT IDENTIFICATION	144	—	—	—	—		
TOTAL	1230	466	335	96	49	103	196

[1] Problems caused by an infectious disease causing agent, e.g. fungus, bacterium, virus, mycoplasma, nematode.

[2] Problem caused by noninfectious environmental stress, e.g. wind, drought, heat, soil compaction.

[3] Problem caused by herbicide/pesticide misuse.

[4] Problem caused by a nutrient imbalance.

[5] Problem caused by an insect. Does not include samples submitted to Entomology Diagnostic Clinic.

[6] "Other" includes the causal agent categories: No disease, and inadequate sample for diagnosis.

was common during the late summer period on lilac, zinnia, dahlia and numerous other susceptible hosts. Bacterial blight of geranium (*Xanthomonas pelargonii*) and Fusarium wilt of chrysanthemum were the most frequently recorded diseases of greenhouse crops.

Disorders: Severe April freezes caused dieback of the new growth on many ornamentals. A mild, wet November followed by a cold and dry December did not allow proper hardening off of roses resulting in extensive cane injury.

Tree Fruits

Diseases: Fire blight was epidemic in southern Indiana. Many growers reported 1986 as the "worst year ever" for fire blight. Though blight was epidemic in only the southern third of the state, orchards in all areas of Indiana experienced above normal fire blight. Bacterial spot of peach caused extensive leaf yellowing and defoliation in a number of southern Indiana orchards during early spring. Sooty blotch and fly speck were the most noticeable fruit problems on apple.

Disorders: Severe hard freezes in April resulted in extensive fruit bud kill and consequent crop loss of all tree fruits. On apples, Red Delicious suffered the heaviest damage with many growers reporting a complete crop loss. Peach, nectarine and other stone fruits also suffered extensive crop loss. Bitter pit (calcium deficiency disorder) was frequently diagnosed on apple fruit.

Small Fruits

Diseases: Septoria leaf spot and Botrytis fruit rot were very common during late September on raspberry and other brambles. Strawberry leaf diseases were also prevalent during the late summer-early fall period. Black rot of grape was frequently diagnosed on samples from homeowners and commercial growers.

Disorders: Significant crop loss occurred on strawberries due to the severe April freezes. A mild, wet November followed by a cold and dry December did not allow proper hardening off of many brambles resulting in extensive cane injury. Growth regulator drift injury on grapes was frequently diagnosed.

Agronomic Crops

Diseases — Wheat: Yield losses in 1986 were due to several diseases and were estimated to be 26% for the state. Yield losses of 40 to 60% were experienced in many fields, and a few fields were not harvested due to low yield and/or poor quality. *Septoria nodorum glume blotch* (*Leptosphaeria nodorum*) was widespread over the entire state and head scab (*Gibberella zeae*) was extremely severe in the northern half. The mycotoxin deoxynivalenol (DON) was associated with the head scab (*G. zeae*). Some grain was rejected at county elevators due to excessive scabby kernels or low test weight. Test weights of 47 to 50 pounds/bu. were not uncommon in northwestern Indiana. In addition, powdery mildew (*Erysiphe graminis* f. sp. *tritici*), Septoria nodorum leaf blotch (*L. nodorum*) and leaf rust (*Puccinia recondita*) were common foliar diseases. While not rated as severe, stem rust (*Puccinia graminis* f. sp. *tritici*) was observed to be at its highest levels in many years. Take-all (*Gaeumannomyces graminis* var. *tritici*) and barley yellow dwarf (Barley Yellow Dwarf Virus) wre reported, but their significance paled in comparison with the foliar and head diseases. Wheat spindle streak (Wheat Spindle Streak Mosaic Virus) was unimportant in 1986.

Diseases — Corn: Corn diseases were pesky in areas during 1986. In a few localized fields in southern Indiana, northern corn leaf blight (*Exerohilum turcicum* syn. *Helminthosporium turcicum*) Races 1 and 2 caused severe damage. Yield losses of over 50% were reported, especially from fields planted in April and where corn followed corn with reduced tillage practices. Gray leaf spot (*Cercospora zeae-maydis*) was found in several southern Indiana areas, and caused severe yield losses in a few fields. While this disease was observed in southeastern Indiana a few years ago, gray leaf spot was more widespread in 1986 than any previous year. Southern corn leaf blight Race 0 (*Bipolaris maydis*), northern corn leaf spot (*Helminthosporium carbonum*), and common rust (*Puccinia sorghi*) were common in the state. Ear rots caused by *Gibberella zeae*, and *Fusarium moniliforme* were spotty but relatively common. Damage from ear rots was not generally considered severe. Diplodia ear rot (*Diplodia maydis*) was again reported from south central and south eastern counties where corn followed corn with reduced tillage practices. Stalk rots caused by the soil-borne pathogens *Gibberella zeae*, and *Fusarium moniliforme* were widespread and caused severe lodging in many fields in the state. Diplodia stalk rot (*D. maydis*) was reported from some fields in south central and south eastern Indiana. Corn Sorghum Downy Mildew was diagnosed for the first time at the Purdue Agronomy Farm, West Lafayette.

Diseases — Soybean: Heavy rainfall during the last half of May resulted in flooding damage and seedling blights (*Phytophthora megasperma* var. *sojae* and *Pythium* spp.) in many of the fields that were planted prior to the start of the wet weather. Rhizoctonia root rot (*Rhizoctonia solani*) was again observed to be moderately severe in some fields. Phytophothora root rot (*P. megasperma* var. *sojae*), brown stem rot (*Phialophora gregata*) and charcoal root rot (*Macrophomina phaseolina*) were soil-borne diseases that were observed in areas of the state and occasionally caused significant yield losses. Sclerotinia stem rot (*Sclerotinia sclerotiorum*) was again observed in a few eastern Indiana fields. The soybean cyst nematode (*Heterodera glycines*) continued to spread into previously unreported areas. Johnson and St. Joseph counties were confirmed to have soybean cyst nematode infestations for the first time in 1986. Sudden Death Syndrome was observed in a few counties, primarily in southwestern Indiana, but the occurrence and severity of this disorder was much less severe than in 1985. The dry August weather that occurred throughout the state is assumed to be partially responsible for the reduced incidence and severity. Pod and stem blight (*Diaporthe phaseolorum* var. *sojae* or *Phomopsis* spp.) and seed molds (various fungi) were reported to be severe in those fields that were harvested after the fall rains.

Diseases — Alfalfa: Common leaf spot, *Leptosphaerulina* leafspot, and stem anthracnose were commonly diagnosed. Phytophthora root rot and crown root rot complex were also noted.

Turfgrasses

Diseases: As in previous years (4, 5, 6, 7) leaf spot and melting out disease caused by *Dreschlera* spp. were common during May and June. In some areas, this disease complex was severe. Necrotic ring spot (*Leptosphaeria korrae*) and summer patch (*Phialophora graminicola*) were moderately severe in Kentucky bluegrass turfs during the summer months. *L. korrae* was also diagnosed in a bentgrass specimen from a putting green in the Indianapolis area. Dollar spot (*Lanzia* spp. or *Moellerodiscus* spp.), Pythium (*Pythium* spp). and brown patch (*Rhizoctonia solani*) were commonly reported on bentgrasses. Rusts (*Puccinia* spp.) were widespread on several turfgrass species. Red thread (*Laetisaria fuciformis*) was diagnosed but appeared to be a minor sporadic problem. Fairy rings and various mushrooms were common complaints during 1986.

Disorders: The months of July and August were very dry, and the combination of drought and near-normal summer temperatures resulted in considerable stress on turfgrasses throughout the state. This stress alone or in combination with disease or other stress resulted in considerable damage to turf areas.

Vegetables

The 1986 growing season witnessed the occurrence of a wide variety of vegetable diseases. Some resulted in severe local problems, but few developed into serious epidemics of regional proportions. The most unexpected observation was the marked decline in incidence of bacterial canker of tomato. (*Clavibacter michiganese* pv *michiganese*). Bacterial canker was diagnosed in very few (less than 5%) fields in 1986 compared with its occurrence in more than 90% of Indiana tomato fields in 1985. The most expected observation was the attack on cucurbits by powdery mildew (*Sphaerotheca fuliginea*). Fortunately, Indiana growers were well prepared for the assault and reduced losses with a variety of control tactics. The following paragraphs document major vegetable diseases that occurred in 1986.

Diseases — Crucifers: Early season crucifers escaped the usual, major diseases (1, 2, 3, 4, 5). However, white rust (*Albugo candidans*) was identified on cauliflower, horseradish, and mustard greens in the northern part of the state. The greens were most severely affected by this disease which has not been identified in Indiana in the past five years. Diseases diagnosed on late season crucifers included black rot (*Xanthamonas campestris*) downy mildew (*Peronospora parasitica*), and club root (*Plasmodiophora brassica*). The fact that black rot was particularly widespread probably coincides with the wet weather that occurred in September and early October.

Disorder — Crucifers: Brown bud of broccoli, a physiological disorder was diagnosed in several fields and also was associated with excess moisture.

Diseases — Cucurbits: Bacterial wilt of muskmelon (*Erwinia tracheiphila*) was more severe in 1986 than in past years. The incidence of wilt was high also among cucumbers, squash, and pumpkins. Fusarium wilt of watermelon (*Fusarium oxysporum* f. sp. *niveum*) and muskmelon (*F. oxysporum* f. sp. *melonis*) continues to be well managed with resistant melon cultivars. Gummy stem blight (*Didymella bryoniae*) developed into a severe problem on irrigated watermelons. Fungicides provided adequate control where overhead irrigation was not used. The same fungus caused black rot of squash and pumpkin and occurred with moderate frequency. Alternaria leaf blight (*Alternaria cucumerina*) remains the most important disease of muskmelons. Production normally is discontinued in most muskmelon fields in southwestern Indiana because foliage is consumed and plants are killed by Alternaria infections. Powdery mildew was observed in muskmelon fields as early as June 16. It created economic problems on muskmelons, squash, and pumpkins in fields where no attempt was made to control the mildew. Downy mildew (*Pseudoperonospora cubensis*) occurred on late season cucurbits such as butternut squash and pumpkins but did not appear to cause economic problems.

Diseases — Tomatoes, Peppers, and Potatoes: Bacterial speck (*Pseudomonas tomato*) and Septoria leaf spot (*Septoria lycopersici*) were the two most troublesome diseases of tomatoes. Fresh market losses to Septoria leafspot were especially severe in some fields; the disease was not a problem in many others. Early blight (*Alternaria solani*) and anthracnose (*Colletotrichum coccodes*) occurred with regular frequency in most fields and caused major problems in a few. Bacterial spot (*Xanthamonas vesicatoria*) was not diagnosed on tomatoes but caused extensive losses to many bell pepper fields. Several direct-seeded pepper fields suffered total losses to bacterial spot, an indication that the pathogen was seed-borne. Damping off and wire stem of pepper seedlings caued by *Rhizoctonia solani* occurred to a very minor extent in northern Indiana. The most frequent disease problems observed on potatoes were scab (*Streptomyces scabies*) and Rhizoctonia canker.

Discussion

Every year plant diseases continue to destroy the farmers' crops, the gardener's vegetables, the home maker's flowers, the trees, shrubs, and lawns which beautify our homes. Occasionally fungi bring about human illness and are responsible for poor gains in livestock as a result of contaminated hay and grain.

Plant diseases are saboteurs of efficient agriculture and the spoilers of suburban beauty. Many plant diseases can be controlled or prevented but as in human medicine there are still some which defy efforts of the scientists to unravel their mysteries. Nevertheless, it is up to those of us entrusted with the task of promoting better farming and better living to realize that we have always with us many unseen competitors for our foodstuffs and many destroyers of our ornamental plants. Through proper understanding of the ways in which plant diseases develop and by promoting and encouraging proper methods of prevention or control a great majority of our plant diseases can be controlled and the losses that they cause materially reduced.

Literature Cited

1. Evans, G.E., D.H. Scott, and P.C. Pecknold. 1980. A Compilation of Plant Diseases and Disorders in Indiana - 1980. Proc. Indiana Acad. Sci. 90:91-104.
2. Evans-Ruhl, G.E., R.X. Latin, P.C. Pecknold, and D.H. Scott. 1981. A Compilation of Plant Diseases and Disorders in Indiana - 1981. Proc. Indiana Acad. sci. 91:20-139.

3. Pecknold, P.C., W.R. Stevenson, and D.H. Scott. 1974. A Compilation of Plant Diseases and Disorders in Indiana - 1974. Proc. Indiana Acad. Sci. 84:71-84.
4. Ruhl, G.E., R.X. Latin, P.C. Pecknold, and D.H. Scott. 1982. A Compilation of Plant Diseases and Disorders in Indiana - 1982. Proc. Indiana Acad. Sci. 92:97-117.
5. Ruhl, G.E., R.X. Latin, P.C. Pecknold, and D.H. Scott. 1983. A Compilation of Plant Diseases and Disorders in Indiana - 1983. Proc. Indiana Acad. Sci. 93:103-120.
6. Ruhl, G.E., R.X. Latin, P.C. PEcknold, and D.H. Scott. 1984. A Compilation of Plant Diseases and Disorders in Indiana - 1984. Proc. Indiana Acad. Sci. 94:145-150.
7. Ruhl, G.E., P.C. Pecknold, D.H. Scott, and R.X. Latin. 1985. A Compilation of Plant Diseases and Disorders in Indiana - 1985. Proc. Indiana Acad. Sci. 95:115-119.

Differential Sensitivity of Muskmelon and Watermelon Cultivars to Ozone-induced Foliar Injury

Michael Simini, Richard G. Snyder and James E. Simon
Department of Horticulture, Purdue University
West Lafayette, Indiana 47907

Introduction

Watermelon and muskmelon are the most important horticultural crops in southwestern Indiana, cultivated on more than 1200 and 600 hectares annually, respectively, in a five-county area of southwest Indiana (1). Recently, the commercially grown melon crops in this region have sustained considerable foliar injury caused by the air pollutant, ozone (3, 8). Ambient levels of ozone (O_3) have also caused foliar injury on O_3-sensitive bioindicator plants grown in 13 sites in southwestern Indiana (10). The O_3-induced foliar injury on muskmelons and watermelons grown in this region is distinct but similar to injury induced by nutritional imbalances (magnesium deficiency and manganese toxicity) (11).

The relationship between foliar injury, growth, and yield is not known. However, maintaining the plant canopy throughout the harvesting period is very important for the normal development of melon fruit. Chlorosis and necrosis of the adaxial leaf surface caused by O_3 may result in reduced photosynthetic capacity which may affect the set, size, and carbohydrate content of the fruit. Premature leaf abscission and leaf degradation caused by high levels of O_3 expose immature fruits to the sun, which could result in sunscald, uneven ripening, and production of unmarketable mature fruits.

Understanding the relative sensitivity of melon cultivars to air pollution stress is important in order to select cultivars for planting in areas of high O_3 pollution. Recent studies (3, 8), have shown that there is a differntial foliar response of melon cultivars to O_3. Thus, the objective of this study was to evaluate a wide range of commercially available cultivars and experimental germplasm not yet released, in order to identify O_3-tolerant muskmelon and watermelon genotypes.

Materials and Methods

This study was undertaken at the Southwest Purdue Agricultural Center (SWPAC) in Vincennes, Indiana, to determine the extent of foliar injury on muskmelon and watermelon cultivars. Each genotype was first seeded in the greenhouse, then transplanted to the field in a randomized complete block design with 3 or 4 replications as previously described (3, 8). Black plastic mulch and trickle irrigation were used, and standard cultural practices (9) were followed throughout the growing season. Ambient O_1 concentrations were monitored and recorded as previously described (8, 10).

Foliar injury was rated visually during the growing season and was based on the percentage of ozone injury (0-100%) on the leaves in each plot. It should be noted that the visual injury ratings were taken on melons that were part of the annual statewide vegetable cultivar trials, some of which were evaluated (replicated) while others were only observed (non-replicated). This accounts for the lack of consistency in the inclusion of the same set of cultivars in each year and trial.

Results

Injury appeared as a chlorosis and necrosis of the adaxial leaf surface. Most muskmelon and watermelon lines grown during 1985, 1986, and 1987 exhibited some degree of O_3-induced foliar injury. A differential response to O_3 was observed among cultivars of both melon species (Table 1). In general, watermelons exhibited more foliar injury than did muskmelons.

TABLE 1. Evaluation of Ozone-Induced Foliar Injury of Muskmelon and Watermelon Cultivars at Vincennes, Indiana, 1985, 1986, and 1987.

		Visible Leaf Injury (%)[z]		
Cultivar	Seed Source	1985	1986	1987
Muskmelon Cultivars[y]				
HXP 3592	HM	50 a[x]	—	8 abc
Bush Star	PS	40 a	—	—
Earlisweet	PS	20 b	17 a	14 a
Superstar	HM	17 bc	8 cde	10 abc
Goldstar	HM	17 bc	—	—
Harper Hybrid	HM	17 bc	—	0 c
Mission	AS	17 bc	—	—
Hiline	AS	—	15 ab	18 a
Laguna	AS	13 bcd	13 abc	15 a
Summet	AS	13 bcd	5 cde	11 ab
Star Trek	HM	13 bcd	7 cde	—
Alaska	PS	10 bcd	—	—
XPH 5015	AS	10 bcd	—	—
XPH 5016	AS	10 bcd	—	—
XPH 5091	AS	10 bcd	—	—
XPH 5089	AS	10 bcd	—	—
Roadrunner	PS	10 bcd	2 e	13 ab
Supermarket	HM	8 bcd	—	—
Classic	PS	8 bcd	12 bcd	—
Allstar	AS	—	8 cde	9 abc
No. 45 SJ	AS	7 cd	—	—
NCX 767	HM	7 cd	—	—
HY-Mark	PS	7 cd	—	—
Saticoy	HM	7 cd	5 cde	14 a
Aurora	AS	—	5 cde	10 abc
Top Mark	PS	3 d	7 cde	3 bc
Market Star	PS	—	3 de	9 abc
Pulsar		—	—	9 abc
Zenith	AS	—	—	11 ab
Watermelon Cultivars				
Early Star	PS	84 a	—	—
Blue Belle	AS	78 ab	—	—
XPH 957	AS	73 ab	—	—
Sundance	AS	—	57 a	—
PS19981	PS	60 abc	53 ab	62 a
Crimson Sweet	AS	55 bcd	37 abcd	58 a
XPH 5078	AS	54 bcd	—	—
XPH 5084	AS	50 bcd	—	—
AU Producer	HL	—	33 bcd	27 b
Royal Sweet	PS	35 cde	20 de	52 ab
MOX 1568	HM	32 de	43 abc	—
Oasis	HM	23 ef	33 bcd	43 ab
Jubilee	HM	23 ef	27 cde	30 b
XPH 5083	AS	17 fg	—	—
Royal Crimson	PS	17 fg	—	—
XPH 962	AS	10 fgh	—	—
Royal Windsor	PS	10 fgh	27 cde	48 ab
Iopride	HM	10 fgh	—	—
Charleston Gray 133	SS	10 fgh	—	—
Charleston Gray	AS	10 fgh	17 de	45 ab
Prince Charles	PS	5 gh	20 de	38 ab
Royal Jubilee	PS	3 h	8 e	38 ab
Madera		—	—	52 ab

---

[z] Rated as percent leaf area with visible injury

[y] Seed sources included: Asgrow (AS), Harris-Moran (HM), Hollar Seeds (HL), Petoseeds (PS), and Sunseed (SS).

[x] Mean separation for each crop within columns by Duncan's Multiple Range Test, 5% level.

The degree of foliar injury of muskmelon cultivars varied among years, although the year effect was not statistically analyzed (Table 1). Six of the nine cultivars had less foliar injury in 1986 than in 1985. In 1987, nine of 11 cultivars had more visual injury than in 1986, while five of nine cultivars had less injury than in 1985. The genotypes exhibiting the most O_3-induced foliar injury were 'HXP3592' and 'Bush Star' in 1985; 'Earlisweet', 'Hiline', and 'Laguna' in 1986; and 'Earlisweet', 'Hiline', 'Laguna', and 'Saticoy' in 1987. The cultivars which had greatest ozone damage in two or more years were 'Earlisweet', 'Hiline', and 'Laguna', but it should be noted that all cultivars were not evaluated every year.

Cultivars with the lowest damage ratings were 'Top Mark' in 1985, 'Roadrunner' in 1986; and 'Harper Hybrid' in 1987. Most genotypes were intermediate in foliar sensitivity to O_3.

Visual leaf injury also varied among the watermelon genotypes (Table 1). The smaller fruited (less than 8 kg avg. fruit wt.), spherical watermelon cultivars such as 'Early Star', 'Blue Belle' and 'PSI9981' were among the most sensitive cultivars to O_3-induced injury. Among the medium to large watermelon types, 'Crimson Sweet', 'Jubilee' and 'Royal Jubilee' exhibited the least amount of foliar injury. The injury ratings also varied among years. The foliar injury was higher in 1986 than in 1985 in 7 of 10 cultivars. In 1987, nine of ten cultivars had more leaf injury than in 1986, while nine of nine had more injury than in 1985. The watermelon cultivars with the most leaf injury included 'Early Star' in 1985, 'Sundance' in 1986, and both 'PS19881' and 'Crimson Sweet' in 1987. Those with the least damage were 'Royal Jubilee' in 1985 and 1986, and 'AU Producer' and 'Jubilee' in 1987.

Based upon visible leaf injury, melon genotypes could be classified according to their relative tolerance to ozone injury. The relative sensitivity of selected minor and newer genotypes were evaluated in a separate study in 1986 and 1987 and also indicate significant differential sensitivity among those evaluated (Table 2).

TABLE 2. Evaluation of Ozone-Induced Foliar Injury on New and Minor Muskmelon and Watermelon Cultivars at Vincennes, IN, 1986 and 1987.

Cultivar[z]	Seed Source	Visual Leaf Injury (%)[y]	
Muskmelons		1986	1987
Early Dawn	Harris	40	20
Earligold F_1	Hollar	23	20
Delicious 51	Harris	17	—
HSR 294	Hollar	17	—
Earlimark	Hollar	13	0
Schoon's Hard Shell	Twilley	7	5
Harvest Queen	Twilley	3	10
Pulsar	Petoseeds	3	—
XPH 5091	Asgrow	3	—
Watermelons			
Charlita Improved	NX[x]	60	85
85-5458 (NZ)	NZ	60	—
85-5453 (NZ)	NZ	50	—
Sweet Home	NZ	50	70
XPH 5084	Asgrow	30	50
Sunshade	Asgrow	20	10
Carmen F_1	Hollar	20	—
Dixie Lee	Twilley	20	45
XPH 5078	Asgrow	10	65
AllSweet	Twilley	10	50

[z] Muskmelon leaf injury based on replicated plots and watermelon leaf injury based on unreplicated plots.
[y] Rated July 22, 1986, and August 12, 1987, as percentage of leaf area with visible injury.
[x] NZ = Nickerson-Swann.

The time at which foliar injury is rated for watermelon is important. While on June 25, 1985, 'Early Star', 'Crimson Sweet', 'Jubilee', and 'Charleston Gray' had no O_3-induced foliar injury, on July 17, injury was present on all cultivars except 'Charleston Gray' (Figure 1). By August 6, a distinct differential response to O_3 was observed among the cultivars, with 'Early Star' and 'Crimson Sweet' showing much more visual injury than the other cultivars. A similar differential response was observed on watermelons in 1986 (Figure 2), and has been reported elsewhere for muskmelon (8).

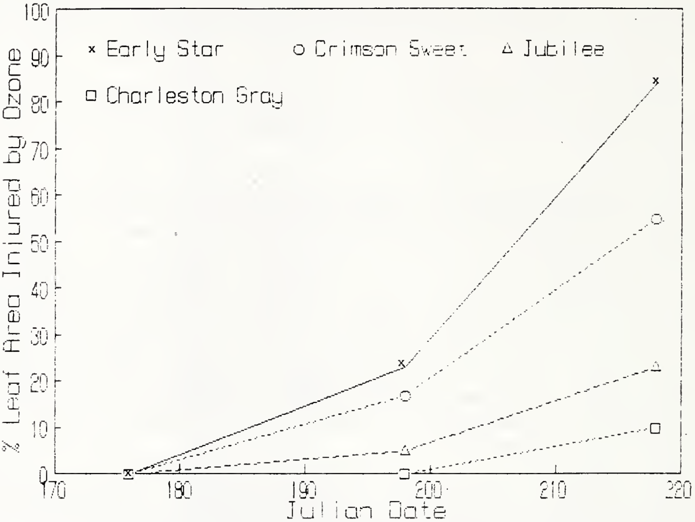


FIGURE 1. Comparison of foliar sensitivity of the 'Early Star', 'Crimson Sweet', 'Jubilee', and 'Charleston Gray' watermelon cultivars grown in Vincennes, Indiana and exposed to daily ambient O_3 concentrations of 0.062 ppm, from May 1 - August 31, 1985.

Tolerance of muskmelon and watermelon genotypes appears to be related to the date of maturity. In general, those cultivars which had the greatest percentage of mature fruit at an earlier date sustained more foliar injury than those which matured at a later date. For example, 81% of the sensitive muskmelon cultivar 'Bushstar' was harvested by August 2, 1985, while only 3% of the tolerant 'Top Mark' was harvested by this time. With watermelon, 81% of 'Early Star' and 52% of 'Crimson Sweet' were harvested by August 9, 1985. These cultivars were more sensitive to ozone than 'Royal Jubilee', of which only 4% was harvested by this date.

The location of injury on the plant is an important factor to consider in the assessment of foilar injury. In watermelon, the 'crown' leaves (older mature leaves about the main stem) had a greater percentage of leaf area injured when compared to the entire plant (Figure 3).

To assess potential differences between the standard and newer generation breeding lines, the cultivar 'Crimson Sweet' was compared to 'Royal Sweet'; 'Jubilee' to 'Royal Jubilee'; and 'Charleston Gray' to 'Prince Charles'. Some of the newly developed cultivars exhibited marked reductions in the degree of foliar breakdown compared to older standard parents from which in part they were developed. Foliar injury of 'Royal Sweet' and 'Royal Jubilee' was considerably less than 'Crimson Sweet' and 'Jubilee', (Figure

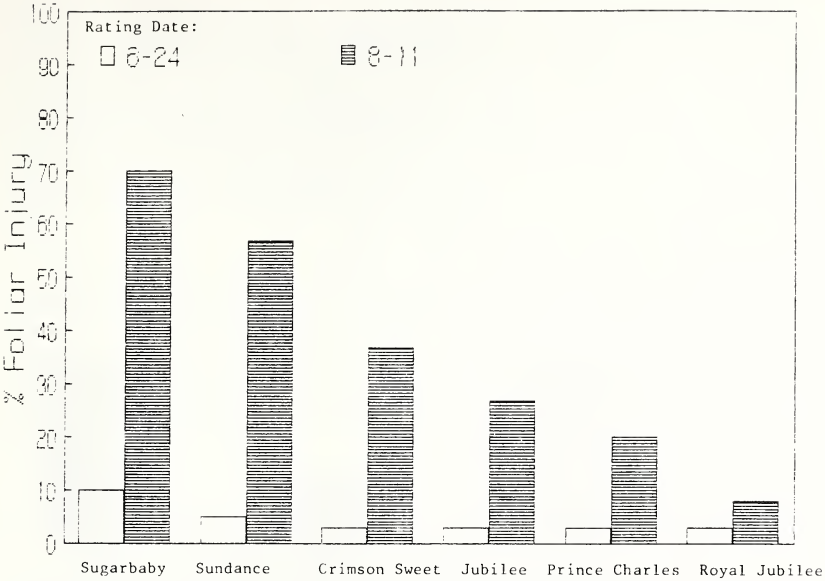


FIGURE 2. Comparison of O_3-induced foliar injury of watermelon cultivars, visually rated June 24 and August 11, 1986.

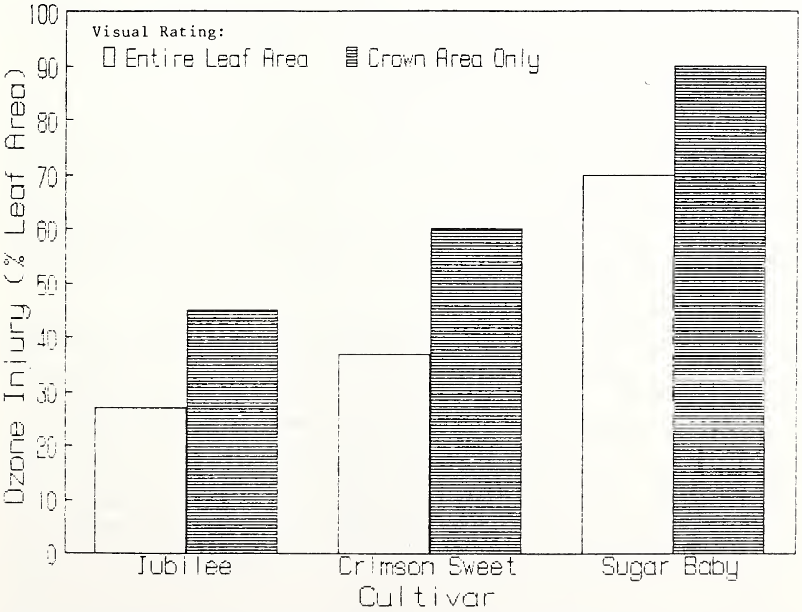


FIGURE 3. Different methods of rating ozone injury on watermelon. Vincennes, Indiana, visually rated August 11, 1986.

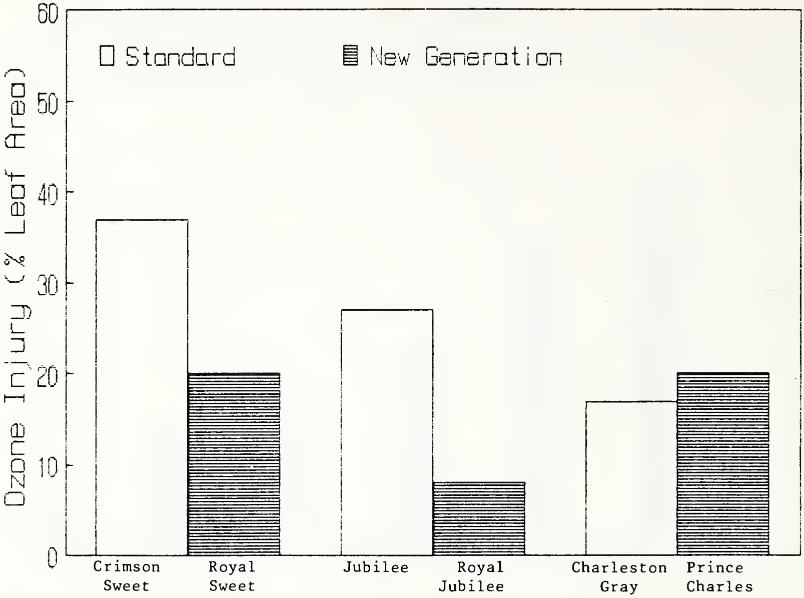


FIGURE 4. Differential sensitivity to O_3-induced foliar injury by newer generation watermelon lines. Visually rated August 11, 1986.

4). 'Prince Charles', a newer release of the 'Charleston Gray' watermelon, had approximately the same amount of foliar injury.

Discussion

This study has shown a differential sensitivity of muskmelon and watermelon cultivars to O_3-induced foliar injury and suggests possible explanations for this differential response. Differences in injury from year to year indicate that the environment affects a plant's susceptibility to O_3 stress and that seasonal O_3 concentrations vary from year to year. Cultivars must be screened over a multi-year period to determine their relative tolerance to O_3-induced foliar injury, and this criterion should be included in muskmelon and watermelon breeding programs.

The stage of development at which the melon plants sustain the most injury can be critical with respect to the effect on marketable yield. Early maturing cultivars, favored for commercial production, were more sensitive than later maturing cultivars. The watermelon cultivar 'Early Star' had the greatest increase in foliar injury (61%) between July 17 and August 6, when 80% of its fruit were harvested. The later maturing cultivars, 'Jubilee' and 'Charleston Gray', had much lower increases in the rate of visible foliar injury. Clark et. al. (2) reported similar results with potato cultivars. One possible reason for this response is that the highest concentrations of O_3 were present (10) at the time when sensitive cultivars had the greatest portion of leaves fully mature, and mature leaves are known to be most sensitive to O_3 injury (4, 5, 7). Furthermore, the rapidly maturing cultivars may have a higher metabolic rate and absorb greater amounts of ozone. A higher metabolic rate could influence both the carbohydrate and nutrient status of the leaves, particularly when the developing fruits are strong sinks for photosynthate and minerals.

The slower growing, later maturing melon cultivars appear to be less susceptible to foliar injury and thus may be correspondingly less susceptible to yield reductions. However, total marketable yield production may not be correlated with foliar breakdown. Previous studies with other crops have shown that yield reductions may occur without visible injury (6, 7). Further investigations are necessary to determine the relationship, if any, between visible injury, foliar degradation, and yield response in melons. If a positive correlation is found between foliar injury and yield response, the use of foliar injury indices would allow for the rapid screening of melon genotypes suitable for introduction into areas with high concentrations of air pollution.

Acknowledgments

This research was supported in part by the United States Department of Agriculture (Cooperative Agreement Research Grant No. 58-5114-4-6001) and the Purdue University Agricultural Experiment Station (Grant No. 425-1165-0035-65078). The authors wish to acknowledge R. Reinert and W. Heck, USDA/ARS National Air Quality Program, Raleigh, North Carolina for their valuable comments during this study. We also express our appreciation to Meb Lang, Superintendent of the Southwest Purdue Agr. Center for his assistance and cooperation in the maintenance of our field plots.

Literature Cited

1. Bureau of the Census. (1984). 1982 Census of Agriculture, Vol. 1. Geographic Area Series. Part 14. Indiana State and County Data. AC82-A-14. U.S. Dept. of Commerce, Superintendent of Docs., Washington, D.C.
2. Clarke, B.B., M.R. Henninger, and E. Brennan. 1983. An assessment of potato losses caused by oxidant air pollution in New Jersey. Phytopath. 73(1):104-108.
3. Decoteau, D.R., J.E. Simon, G. Eason, and R.A. Reinert. 1986. Ozone-induced injury on field-grown watermelons. HortScience 21(6):1369-1371.
4. Heggestad, H.E. and W.W. Heck. 1971. Nature, extent and variation of plant response to air pollutants. Adv. Agron. 23:111-145.
5. Hill, A.C., H.E. Heggestad, and S.N. Linzon. 1970. Ozone p.B1-B22, In: J.S. Jacobsen and A.C. Hill (eds). Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas. Air Pollution Control Assoc., Pittsburgh, PA.
6. Legassicke, B.C. and D.P. Ormrod. 1981. Suppression of ozone-injury on tomatoes by ethylene diurea in controlled environments and in the field. HortScience 16(2):183-184.
7. National Research Council. 1977. Ozone and Other Photochemical Oxidants. National Academy of Sciences. Washington, D.C. 719 pp.
8. Simini, M., J.E. Simon, G. Eason, and R.A. Reinert. 1988. Identification of ozone-induced injury on field-grown muskmelon. HortScience:(Submitted).
9. Simon, J.E., R.X. Latin, and D.L. Matthew (eds). 1987. Indiana Vegetable Production Guide for Commercial Growers. Purdue Univ. Coop. Ext. Serv. ID 56. pp.28-36.
10. Simon, J.E., M. Simini, D.R. Decoteau, W. McFee, K. Scheeringa, and J.E. Newman. 1986. Monitoring air pollution for its potential impact on agricultural crops in SW Indiana. Proc. In. Acad. Sci. 95:289-301.
11. Simon, J.E., G.E. Wilcox, M. Simini, O.M. Elamin, and D.R. Decoteau. 1986. Identification of manganese toxicity and magnesium deficiency on melons grown in low-pH soils. HortScience 21(6):1383-1386.

CELL BIOLOGY

Chair: John W. Munford
Department of Biology
Wabash College
Crawfordsville, Indiana 47933 (317) 364-4202

Chair-Elect: Steven T. Barefoot
Department of Medical Research
Methodist Hospital
1604 Capitol Ave.
Indianapolis, Indiana 47933 (317) 929-5392/929-8862

ABSTRACTS

Effects of Retinoids on Phospholipid Bilayers. Mark Albrecht and William Stillwell, Department of Biology and Stephen R. Wassall, Department of Physics, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.——Retinoids representing each of the three oxidation states (all trans-retinol, retinal and retinoic acid) were incorporated into phospholipid bilayers and the effects on membrane permeability, acyl chain motion and phase transition temperature studied. Retinoic acid was shown to greatly enhance permeability of PC (phosphatidylcholine) bilayers to the non-electrolyte erythritol and to the fluorescent anion carboxyfluorescein. Retinol and retinal enhance permeability to a much less extent. This distinction between retinoid enhancement of permeability correlates with differences seen in the effects on ESR (electron spin resonance) order permaeter S and phase transition temperature T_c.

Development of the Neostriatum in the Rat Brain. Shirley A. Bayer, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.——Neurogenesis in the rat neostriatum was examined with [^{3}H] thymidine autoradiography, a quantitative method which allows the exact determination of the proportion of neurons originating in a given population over a 24 hr. period. The medium-sized neurons throughout the neostriatum are generated in a prominent ventrolateral-to-dorsomedial gradient so that ventrolateral cells originate mainly between embryonic days (E)14 and E18, dorsomedial cells between E18 and E21-22. Fewer than 10% originate between birth and postnatal day 4. Medium-sized neurons also show two other gradients. First, there is a superficial-to-deep gradient in the anterior part of the caudoputamen, while more posterior levels have a gradient in the opposite direction. Second, anterior parts have a caudal-to-rostral gradient while posterior parts have an opposite gradient. These shifts in neurogenetic gradients between anterior and posterior parts is developmental evidence that an anterior "caudate" can be separated from a posterior "putamen" in the rat. Finally, neurogenetic gradients in the medium sized caudoputamen neurons can be linked to the patterns of their anatomical interconnections with the substantia nigra.

A Comparative Study of the Hamster Kidney Cell Line BHK-21 (C-13) and Normal Hamster Kidney Tissues. Angela M. Burke and Pang Fai Ma, Center for Medical Education, Ball State University, Muncie, Indiana 47306.——Adenosine deaminase catalyzes the deamination of adenosine to inosine in the purine degradative pathway. Multiple molecular species of the enzyme have been found to be diversely distributed among the tissues of lower vertebrates and mammals. These molecular forms correspond to molecular weights of 200,000, 100,000 and 35,000 and have been designated as forms A, B and C, respectively, estimated by gel filtration. All three forms appear to be prevalent among the tissues of lower vertebrates, while only the A and C form enzymes have been found in studies done on higher mammals. Previous studies have indicated that an increase in the activity of adenosine deaminase may be associated with some pathological conditions. In cancerous lung tissues both enzyme forms are present with an elevated ratio of forms C to A indicating an increase in the level of the C form with little or no A form present. This is in comparison with normal lung tissue in which there exists a much smaller such ratio. In this report, we present the results of a study done on the hamster kidney cell line BHK-21 (C-13) and normal hamster kidney tissues. The purpose of this study is to determine the enzyme activity and the relative proportions of the A and C form enzymes in the two systems mentioned.

Adhesion and Expansion of Epithelial Cell Sheets. E.A.G. CHERNOFF, Department of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.———Intact chick extraembryonic epiblasts were cultured on the inner face of the vitelline membrane in a chemically-defined serium-free medium. Epiblasts require the addition of hydrocortisone to attach, but will expand without it. Fusion occurs when edges contact each other. Microfilament organization (visualized by rhodamine-phalloidin fluorescence) changes abruptly between the specialized adhesive edge region and the unattached interior of the cell sheet. Flat (Type I) and ridged (Type II) transition regions are found, and may correlate with specific phases of the expansion process. Small microfilament-containing sites of substratum attachment are revealed by detachment of the epiblast. No exogenous fibronectin or laminin is required for adhesion and the vitelline membrane contains neither adhesive molecule (immunofluorescence, PAGE). The vitelline membrane inner face was separated from other layers using a freeze-thaw process. Disulfide-bond reducing agents are required to dissolve the membrane. Chemical analysis using PAGE and a color-based silver stain shows three principal components.

Identification of Members of Species-groups of Genus *Paramecium* with Fluorescent, DNA-binding Dyes. THOMAS A. COLE, WILLIS H. JOHNSON AND RUCHIR SEHRA, Wabash College, Crawfordsville, Indiana 47933.———Within genus *Paramecium*, members of three species-groups are cylindrical and long, with tapered ends. Species-group *P. aurelia* is distinguishable, on the basis of size, from *P. caudatum* and *P. multimicronucleatum*, which overlap in size and are greater than 180 uM long. *P. caudatum* contains one micronucleus and *P. multimicronucleatum* contains four (or more) micronuclei. Staining with visible dyes is somewhat problematic. Recent confusion on species-group type of the larger forms has resulted from indiscriminate sampling by a biological supply house. The use of fluorescent, DNA-binding dyes to distinguish the micronuclei in these species-groups will be reported. These dyes include acridine orange, ethidium bromide, DAPI (4′, 6-Diamidine-2-phenylindole) and two *bis*benzimide compounds (Hoechst No. 33258 and No. 33342).

Degradation of Liver HMGCoA Reductase in Vitro. DAVID M. GIBSON, STEVEN J. MILLER AND TED GOODSON, III, Indiana University School of Medicine, Indianapolis, Indiana 46223.———HMGCoA reductase has a molecular weight of approximately 97,000. Simple freezing and thawing of lysosomal-contaminated microsomes releases a soluble portion of the enzyme (MW 53,000-62,000). Incubation of washed microsomes with a purified thiol protease, calpain, also results in the generation of an apparently identical fragment. This degradation product appears as a doublet on an SDS-polyacrylamide gel. Centrifugation of calpain-treated microsomes followed by electrophoretic and immunoblot analysis of the supernatents and pellets indicated that the lower mobility band was present in the supernatent. This has implications for the mechanism of reductase degradation.

In another experiment, the ability of chymostatin to inhibit the proteolysis of reductase was examined. This inhibitor is known to block degradation of reductase in hepatocytes, presumably by inhibition of lysosomal proteases. In a freeze-thaw system chymostatin prevented the release of reductase into the supernatent fraction, suggesting that lysosomal degradation is indeed blocked.

Effects of Extracellular Sodium and Calcium on Acetylcholine Induced Hyperpolarizations in Mouse Parotid Cells. A. Gubitosi and R.J. Stark. DePauw University, Greencastle, Indiana 46135.——Studies with the ionophore A23187 indicate that acetylcholine (ACh) induced membrane hyperpolarizations may be dependent on changes in cytosolic Ca^{++} or Na^{+}. To examine any ionic effects, acinar cell membrane potentials (Em) were measured during Ach (10^{-8} to 10^{-5}M) stimulation in a mammalian Ringer's, Ca-free Ringer's, or Na-free TRIS Ringer's sol'n. The induced changes in Em with and without extracellular calcium were not significantly different (P 0.2). The presence or absence of extracellular sodium (oNa) also had no effect on the Em hyperpolarizations at ACh conc. 10^{-6}M. Normally, higher ACh concs. fail to produce any further increase in Em. However, when oNa was removed, Em continued to increase. These results suggest that a sodium dependent negative feedback mechanism is activated at higher concentrations of ACh which inhibit the cell's response to the stimulus. This inhibition is eliminated in the absence of oNa or when the cells are stimulated with A23187 which bypasses the ACh activated ion channels. (Supported by a DePauw Faculty Development Grant)

Influence of Dietary Fatty Acids on Murine Mammary Cell Types. Michael I. Lee, Scott A. Smith and Alice S. Bennett, Ball State University, Muncie, Indiana 47306.——Experiments were performed to determine whether dietary induced alterations in the fatty acid distributions observed in intact mammary glands and white adipose tissues were reflected in distributions in mammary epithelium and adipocytes. Intraperitoneal white fat and mammary glands were removed from 5 mo. old Strain A/ST mice fed high fat diets rich in either stearic acid or linoleic acid or low fat diets. Mammary glands were enzymatically digested; epithelial cells and adipocytes were separated by differential centrifugation. Fatty acid distributions were determined by gas liquid chromatography. Results indicate that the fatty acid composition of mammary adipocytes was similar to the intraperitoneal white fat and intact mammary glands in each dietary group, but differed significantly from that of mammary epithelium.

Fatty acids have been demonstrated to affect the tumorigenic process. These studies should help determine whether the tumorigenic effect of dietary fatty acids is the result of alterations in the lipid structure of the epithelial cells or the availability of fatty acids in the closely associated adipocytes.

Con A Binding Sites in the Ciliate *Stentor coeruleus* Are Located in the Membranellar and Somatic Cilia. Michael S. Maloney and Jeannette L. Daniel, Department of Biological Sciences, Butler University, Indianapolis, Indiana 46208.——Previous studies had shown that Concanavalin A (Con A) inhibits the regeneration of a new oral feeding apparatus (oral regeneration) in the ciliate *Stentor coeruleus*. To extend these studies, we examined the initial location of the Con A binding sites by fixing nonregenerating and regenerating cells prior to exposure to FITC-Con A. When examined by fluorescence microscopy, the cells showed a bright fluorescence in the membranellar cilia that are a part of the oral apparatus and in the somatic (body) cilia. Regenerating cells revealed a striking fluorescence in the developing oral primodium at all stages of regeneration. Binding of the FITC-Con A was prevented by the presence of 50 mM α-D-methyl mannoside. The results demonstrate that membrane glycoproteins capable of binding Con A are present in the membranellar and somatic cilia in *Stentor* and that the effects of

Con A on oral regeneration may be related to these membrane proteins. Supported by grants from NSF and the Research Corporation and a Butler University Fellowship.

Diabetes-induced Decrease in Sodium Pump Activity in Rat Soleus Muscle. JOHN W. MUNFORD AND JOSEPH E. TRUMPEY, Wabash College, Crawfordsville, Indiana 47933.——The hypothesis that insulin regulates sodium pump activity *in vivo* was tested in this study by assessing the effects of streptozotocin-induced diabetes on the number and activity of sodium pump sites in rat soleus muscle. In rats made diabetic by a single intraperitoneal injection of streptozotocin (SZ), (75mg SZ/kg body wt.) plasma insulin and thyroid hormone (T_4) levels wre decreased to less than 50% of control levels. Associated with these hormonal changes were a 48% decrease in the rate of total ^{22}Na efflux and a 36% decrease in the rate of ouabain-sensitive ^{22}Na efflux. These decreases in the rates of ^{22}Na efflux seem to result from a decreased number of sodium pump sites since soleus muscles from diabetic rats bind 47% less ^{3}H-ouabain than muscles from control rats. The data of this study suggest that a complex relationship exists between the circulating levels of insulin and thyroid hormone and the number and activity of sodium pumps in mammalian skeletal muscle. This study was supported by a grant from The American Diabetes Association, Indiana Affiliate, Inc.

Effect of Caffeine on Contractility of Frog Skeletal Muscle. BRUCE PICKELHEIMER AND RICHARD S. MANALIS. Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——Experiments were performed on the frog sartorius neuromuscular preparation to determine the effects of caffeine on muscle contractility. The experiments were also designed to determine whether the effects were a result of presynaptic increases in the amount of neurotransmitter released or a result of postsynaptic increases in the amount of calcium released from the sarcoplasmic reticulum of the muscle. Indirect stimulation of the preparation showed increased contractility of the muscle as the caffeine concentration of the test solution increased. Experiments are currently being conducted by direct stimulation of the preparation in test solutions containing either d-tubocurarine chloride or a combination of high magnesium and low calcium to determine whether the observed effect is presynaptic, postsynaptic, or both.

Neurotransmitter Release Simulation. DANNY LEE ROBERSON AND RICHARD S. MANALIS. Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——A special purpose user-friendly interface program was developed in order to allow for the compartmental modeling of neurotransmitter release at the frog neuromuscular junction. A first step was to write a test program in PASCAL on a VAX computer and then to download the generated data to a personal computer. This simulation duplicated and confirmed the lumped parameter mathematical model reported by K.J. Gingrich and J.H. Byrne in the *Journal of Neurophysiology* of March 3, 1985. The data files generated were successfully downloaded to a personal computer and used as input into a statistical package. Future work is aimed at completing the user-friendly program and to constructing a complex neurotransmitter release model. Factors that determine the ionized [Ca^{++}] present within the nerve terminal, the mobilization of transmitter, and the facilitation and depression of a transmitter release will be incorporated into the model.

Calmodulin Antagonists Inhibit Oral Regeneration in the Ciliate *Stentor coeruleus*. PATRICIA R. WALSH AND MICHAEL S. MALONEY, Department of Biological Sciences, Butler University, Indianapolis, Indiana 46208.——Loss of the oral feeding apparatus of the ciliate *Stentor coeruleus* results in the regeneration of a new one in 8-10 hrs., a process known as oral regeneration. The calcium regulatory protein, calmodulin, has been isolated from several protozoan species and it seemed likely that it might be present in *Stentor* and involved in controlling oral regeneration. We investigated this possibility by examining the effects of several calmodulin inhibitors on oral regeneration. Both trifluoperazine and W-7, classic calmodulin antagonists, inhibited oral regeneration at concentrations as low as 4 uM. An inactive analogue of W-7, W-5, was used as a control for the specificity of action of these inhibitors. W-5 had no effect on oral regeneration even at concentrations up to 60 uM. Excess extracellular calcium could not modulate the effects of W-7 as it had no effect on the delays caused by W-7. These results provide evidence that calmodulin is involved in controlling oral regeneration in *Stentor*. Supported by a grant from the Research Corporation and a Butler University Fellowship.

Serum Angiotensin Converting Enzyme Changes in Rabbits Following Neutrophil Activation *in vivo*. STEPHEN P. ZIMMER AND JOAN E. LAFUZE, Indiana University School of Medicine, Indianapolis, Indiana 46223.——Intravenous infusion of N-formyl-methionyl-leucyl-phenylalanine (FMLP), synthetic analog of the endotoxin of E. coli, causes neutropenia *in vivo*. The sequestered neutrophils may block the microvasculature of the lung, adhere to the pulmonary endothelium and release toxic by-products of oxidative metabolism which may cause endothelial damage and respiratory distress. Because pulmonary endothelium produces angiotensin converting enzyme (ACE) which converts angiotensin I to angiotensin II and degrades bradykinin, we wished to determine whether the I.V. infusion of FMLP (0.2 ug/kg) would elevate serum levels of ACE. Results were calculated as percent change from pre-infusion ACE values and reported as Mean ± S.D. Changes in serum ACE levels were +6.16 ± 5.03%, −5.89 ± 8.16%, +0.630 ± 5.42%, −11.6 ± 7.38% at 5, 10, 15, and 30 minutes post-infusion respectively, compared with controls (−6.70 ± 3.55, −0.910 ± 4.29, −6.06 ± 3.02, and −16.7 ± 6.32); $n = 3$ in each group. Thus FMLP-induced neutrophil activation in rabbits *in vivo* appears to increase serum ACE levels, a possible result of activated neutrophil mediated damage of pulmonary endothelium.

Energy Expenditure and Maximum Life Span

TORSTEN ALVAGER AND THOMAS KING
Department of Physics and Department of Life Sciences
Indiana State University, Terre Haute, Indiana 47809

Introduction

The energy per mass unit (the specific energy) dissipated by an animal during its lifetime is approximately species independent for a large group of animals (see e.g. refs 1 and 2). This remarkable fact can be formulated as follows:

$$T \times SMR = \text{constant}$$

where the product of the maximum life span (T) and the specific metabolic rate (SMR) is approximately a constant. Given the preceding equation and the importance of energy metabolism to an individual it seems apparent that any valid theory of aging must be capable of providing a testable molecular explanation for the relative invariance observed for this relationship. Unfortunately, most existing theories of aging are not developed in sufficient chemical detail to allow a quantitative test of the empirical observation embodied in the above equation. One theory of aging in which chemical events have been studied in sufficient detail to make quantitative discussion possible is the free radical theory of aging (see e.g. refs 3-7). In one of its versions the chemical events leading to aging are those associated with lipid peroxidation. Thus the reactions associated with lipid peroxidation can be regarded as archtype chemical events representing the more general chemical reactions usually associated with the free radical theory of aging. It is the purpose of this report to demonstrate a connection between the chemical events of lipid peroxidation and the relationship between the maximum life span and the specific metabolic rate as stated in the equation given above.

Aging theories based on the chemical reactions of lipid peroxidation assume, as do damage theories in general, that age effects observed at the level of the intact organism are the cumulative result of events occurring at the cellular and subcellular level. Since the latter assumption seems acceptable we can conveniently proceed to divide our problem into two basic parts. The first part consists of chemical events which occur at the subcellular level. The second part includes linked processes which transform the latter chemical events to effects on the organism as a whole. We will first discuss subcellular lipid peroxidation as the archtype chemical event of aging and then relate the derived results to the intact organism.

Subcellular Lipid Peroxidation Reactions

The primary damaging reactions that initiate intracellular lipid peroxidation and the reactions that comprise the chemical changes associated with lipid peroxidation are free radical reactions which involve molecular oxygen and unsaturated lipids (see e.g. ref. 6). These free radical reactions proceed in three general phases: free radical initiation, free radical propagation and free radical termination.

In the initiation phase, free radicals (R) are formed from a molecular precursor. Typical initiation reactions may be written symbolically as

$$\text{initiation} \rightarrow R \qquad (1)$$

In the propagation phase of the reaction these free radicals react to produce lipid hydroperoxides (ROOH) illustrated in the following sequence of reactions:

$$R + O_2 \rightarrow RO_2 \qquad (2)$$

$$RO_2 + RH \rightarrow ROOH + R \qquad (3)$$

Two known radical terminating reactions are illustrated below:

$$2\ RO_2 \rightarrow \text{nonradical products} \tag{4}$$
$$RO_2 + AH \rightarrow ROOH + A \tag{5}$$

AH represents an antioxidant such as vitamin E.

A Life Span vs Energy Expenditure Equation

To a first approximation an overall measure of the effects caused by lipid peroxidation and its homolytic reaction products including damage to tissue is expressed by the oxygen consumption as given by equ. (2) (see e.g. ref. 8). Assuming this approximation it can then be shown, by solving the rate equations corresponding to reactions (1) to (5), that the damage effect is given by the following expression

$$\text{Damage} = D \times t \times \text{rate of initiation} \tag{6}$$

In this relation t is the time during which lipid peroxidation processes have been active and the quantity D is a function which depends on the rate constants for reactions (2) to (5) and concentrations of compounds involved, but not on time and rate of initiation (reaction (1)). This equation shows that the damaging effect to a cell increases linearly with time. This linear dependence is in accord with the observation that the functional capacity of many organs and tissues decreases approximately linearly with age [9]. The formation of age pigments is another example of a linear time dependent phenomenon during aging. The appearance of age pigments, or lipfuscins is generally explained as being caused by lipid peroxidation reactions (see e.g. refs 10 and 11). The concentration of these pigments increases approximately linearly with age in many cells [10, 12]. This experimental observation supports the interpretation of the above relation (eq. 6) as being a measure of damage from lipid peroxidation reactions. This relation can be applied to a cellular situation to obtain a cellular life span versus specific metabolic rate equation.

Assume that at a particular critical time $t = T_c$, the damaging effect P has reached a critical value $[P]_c$. We define this time as being that when irreversible damage to the cell has occurred causing total loss of normal biological function. The critical value, $[P]_c$, is likely to be the same for most species. The repair capacity of a cell may be different from species to species causing the net rate of damage to vary, but as far as the main biological function of the cell is concerned no large species differences exist between analogous cells in the category of animals of interest here (see e.g. ref. 13).

Equation (6) can now be rewritten, for the condition time $t = T_c$ and damage $= [P]_c$ as

$$[P]_c = D \times T_c \times \text{rate of initiation} \tag{7}$$

The quantity rate of initiation in this equation depends on free radicals available in the cell. More specifically, it depends most likely on the hydroxyl radical as the initiator of lipid peroxidation because of its extreme reactivity. It is in general assumed that the production rates of the hydroxyl radical and the superoxide radical are directly related and proportional to the amount of oxygen consumed by the cell [14]. The conclusion is therefore that the initiation rate is proportional to the rate of the oxygen consumption of the cell and therefore also the specific metabolic rate of the cell. Thus the rate of initiation can be written

$$\text{rate of initiation} = (\text{constant})\ (SMR)_{cell} \tag{8}$$

With the help of relation (8) it is now possible to express equation (7) in the following form

$$T_c \times \text{rate of initiation} = T_c\ (\text{constant})\ (SMR)_{cell} = [P]_c/D \tag{9}$$

In other words, the product of the critical time T_c, which corresponds to the maximum life span of a cell, and the specific metabolic rate of a cell $(SMR)_{cell}$ is species independent if $[P]_c$ is constant as assumed above.

The relation between maximum life span T of the intact organism and its specific metabolic rate follows from equation (9) with two additional assumptions: (a) the organism as a whole ages in proportion to the aging of its cells and (b) the total specific metabolic rate is a sum of specific metabolic rates of individual cells. A more detailed discussion of this far from trivial problem of relating cellular properties to those of tissues or intact organisms is found elsewhere (14).

Conclusion

In conclusion we have shown that a cellular theory based on the reactions of lipid peroxidation agrees quantitatively with the empirical law relating maximum life span and specific metabolic rate. No other theory of aging has been shown to be consistent with this empirical law.

Acknowledgment

This research was supported in part by a grant from the Indiana State University Research Committee.

Literature Cited

1. Sacher, G. 1977. Life table modification and life prolongation. In C. Finch and L. Hayflick (eds), *The Biology of Aging*, 582-638, New York: Van Nostrand Reinhold Co.
2. Hemmingsen, A. 1960. Rep. Steno. meml. Hosp. 9: 1-110.
3. Harman, D. 1956. A theory based on free radical and radiation chemistry. J. Gerontol. 11: 298.
4. Balin, A. 1982. Testing the free radical theory of aging. In R. Adelman and G. Roth (eds.), *Testing the theories of aging*, 137-182, Boca Raton: CRC Press.
5. Tappel, A., B. Fletcher, and D. Deamer. 1973. Effects of antioxidants and nutrients on lipid peroxidation, fluorescent products and aging parameters in the mouse. J. Gerontol. 28: 415-421.
6. Vladimirov, Yu., V. Olenev, T. Suslova, and Z. Cheremisino. 1976. Lipid peroxidation in mitochondrial membranes. Advances in lipid research. 17: 173-249.
7. Witting, L. 1980. Vitamin E and lipid antioxidants. In *Free radicals in biology*, 4:306.
8. Uri, N. 1961. Physico-chemical aspects of autoxidation. In W. Lundberg (ed.), *Autoxidation and antioxidants*, 1: 55-106, Interscience, New York.
9. Finc, C. and L. Hayflick (eds.). 1977. *The Biology of Aging*, 582, New York: Van Nostrand Reinhold Co.
10. Strehler, B. 1977. *Time, cells, and aging*, Academic Press, New York.
11. Donato, H. 1982. Lipid peroxidation, cross-linking reactions, and aging. In R.S. Sohal (ed.) *Age pigments*, 63-81, North-Holland, Amsterdam.
12. Alvager, T. and W. Balcavage. 1978. Age related changes in fluorescence and respiratory properties in liver mitochondria. Age 1:42-48.
13. Wilkie, D. 1977. Metabolism and body size. In T. pedley (ed.) *Scale effects in animal locomotion*, 23-36, Academic Press.
14. Cutler, R. 1982. Longevity is determined by specific genes: testing the hypothesis. In R. Adelman and G. Roth (eds.), *Testing the theories of aging*, 25-114, Boca Raton: CRC Press.

Redox-induced Proton Excretion by Cultured Carrot Cells Is Affected by Protonophores and Inhibitors of ATPase

Rita Barr, Owen Martin, Jr. and Frederick L. Crane
Department of Biological Sciences
Purdue University
West Lafayette, Indiana 47907

Introduction

Proton excretion by plant cells in well known. It has been attributed to the action of the H^+-ATPase, located on the cytoplasmic surface of the plasma membrane (13, 15). Recently, redox energy-driven proton pumps have also been described (7-9). The first report of transmembrane ferricyanide reduction associated with H^+ excretion, by Craig and Crane, appeared in these proceedings (2,3). In the present communication we provide evidence that the proton excretion exhibited by cultured carrot cells is derived from two different sources: 1) the action of an H^+-ATPase and, 2) from a transplasma membrane electron transport chain.

Materials and Methods

Carrot cells were grown in 250 ml Erlenmeyer flasks on a rotary shaker in 50 ml of Murashige and Skoog's (10) liquid medium without agar, obtained from K.C. Biological, Inc., Lenexa, KS, 66215. Cells were harvested between 4-8 days by centrifugation in 15 ml centrifuge tubes in a table model unrefrigerated International centrifuge for 2 min. at 1500 r.p.m. They were rewashed 3 times with a sucrose-salts solution (0.1 M sucrose with 10 mM each of KCl, $MgCl_2$ and $CaCl_2$). The final cell pellet was suspended in 50 ml of sucrose-salts solution and placed on a reciprocal shaker or supplied with a thin stream of air from a laboratory airline. Aliquots from this cell suspension were withdrawn for use in assays. These carrot cells remained in good condition for at least 8 hrs.

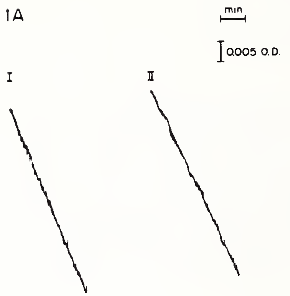
Transmembrane ferricyanide reduction of cultured carrot cells was measured spectrophotometrically with a DW-2A spectrophotometer as the difference between 420 and 500 nm at 24 °C, as previously described (2,3). The initial reaction mixture in 1.5 ml consisted of 25 mM Tris-Mes, pH 7, and 0.005 g cells (dry wt.), and 150 μM FeCN was added to start the reaction after a 3 min. incubation period. In some cases, cells were incubated with inhibitors for up to 30 min. Aliquots of cells were withdrawn every 10 or 15 min. to test for rates of ferricyanide reduction.

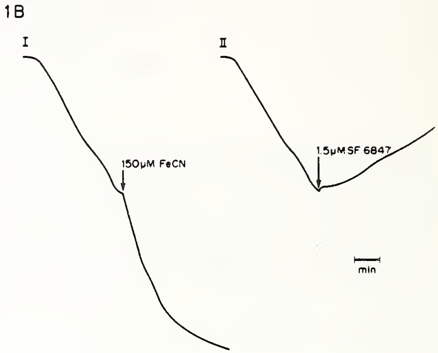
Proton excretion by cultured carrot cells was measured with a combination pH electrode (Corning) in a 5 ml water jacketed cell at 24 °C, gently stirred with a magnetic stirring bar. Additions of uncouplers and inhibitors were made through a sidearm. Air from a laboratory airline, filtered through cotton, was bubbled through the cell suspension from another sidearm of the flask. H^+ excretion was monitored with a Linear model recorder. Rates of H^+ excretion were calculated from the addition of known amounts of HCl to the reaction mixture after every assay.

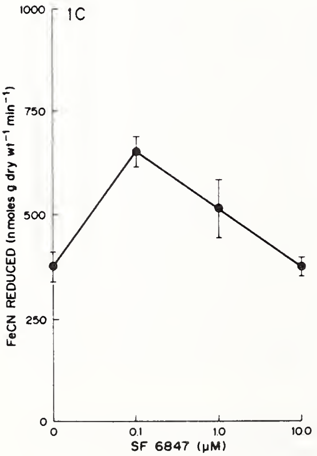
If 5 μl of 0.01 N HCl were added to the reaction mixture after the assay, 0.05 μ equivalents HCl or H^+ resulted, which was equivalent to 50 squares on the chart, for example. The number of squares given by the basal rate (x), divided by 50 squares from the acid, and divided by the dry weight of cells in g, gave the rate of H^+ g dry wt.$^{-1}$ min.$^{-1}$

Results and Discussion

It has recently been acknowledged (4,7-9) that transplasma membrane electron transport can contribute to H^+ excretion by plant cells. This conclusion was based on studies by Craig and Crane (2,3) with cultured carrot cells, Federico and Giartosio (5), Qiu, Rubinstein and Stern (11) and Böttger and Lüthen (1) with maize root segments, Rubinstein, Stern and Stout (12) with oat root segments, Thom and Maretzki (16) with sugarcane protoplasts, Sijmons *et al.* (14) with bean roots and Ivankina and Novak (6)







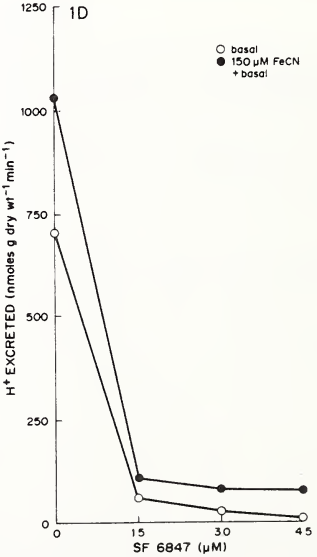


FIGURE 1A. Tracings of Transmembrane Ferricyanide Reduction by Cultured Carrot Cells. I — control rate was 385 nmoles FeCN reduced g dry wt.$^{-1}$ min^{-1}; II — rate with 10 μM SF 6847 was 350 nmoles FeCN reduced g dry wt.$^{-1}$ min^{-1}.

FIGURE 1B. Tracings of H$^+$ Excretion by Cultured Carrot Cells. I — control showing a basal rate of 700 nmoles H$^+$ excreted mg dry wt.$^{-1}$ min^{-1} before the addition of FeCN; 1050 nmoles with FeCN added. II — the rate of H$^+$ excretion in presence of 1.5 μM SF 6847 was 0.

FIGURE 1C. The Effect of SF 6847 on Transmembrane Ferricyanide Reduction by Cultured Carrot Cells. Various concentrations of SF 6847 were added as shown.

FIGURE 1D. The Effect of SF 6847 on H$^+$ Excretion by Cultured Carrot Cells. Various concentrations of SF 6847 were added as shown. Note inhibition of both basal and ferricyanide induced proton release.

with *Elodea* leaves. In the present study, we differentiate between the two sources of protons by comparing the effects of selected ATPase and mitochondria inhibitors on basal and ferricyanide-induced proton release. ATPase inhibitors are expected to inhibit the protons excreted through the action of the H^+-ATPase, and mitochondria electron transport inhibitors are expected to reduce the source of energy, ATP, needed for ATPase action. The amount of ATP available to the cell should not affect transplasma membrane electron transport, since it derives energy from the oxidation of intracellular NADH by the external electron acceptor.

The basic methods of data collection are illustrated in Figure 1, where a tracing of transmembrane ferricyanide reduction (A) portrays plasma membrane electron transport and a tracing of the lowering of pH in the reaction medium (B) illustrates H^+ excretion by carrot cells. Uncouplers, such as SF 6847, show more effect on H^+ excretion (Figure 1D) than on ferricyanide reduction (Figure 1C). The best known ATPase inhibitors, diethylstilbestrol and DCCD, inhibit the basal or ATPase-generated H^+ excretion, while ferricyanide reduction by carrot cells was inhibited about 50% after incubation of cells with the inhibitor for 30 min (Figure 2). Inhibitors of mitochondrial electron transport are very effective in inhibition of the ATP-dependent basal proton release, but have very little effect on the ferricyanide induced proton release (Figure 3).

In summary, the data of this study support the conclusion that H^+ excretion by carrot cells is generated by two separate mechanisms: 1) the action of the plasma membrane H^+-ATase, and 2) transplasma membrane electron transport, measured as ferricyanide reduction by these cells. The proportion from each component varies with growth

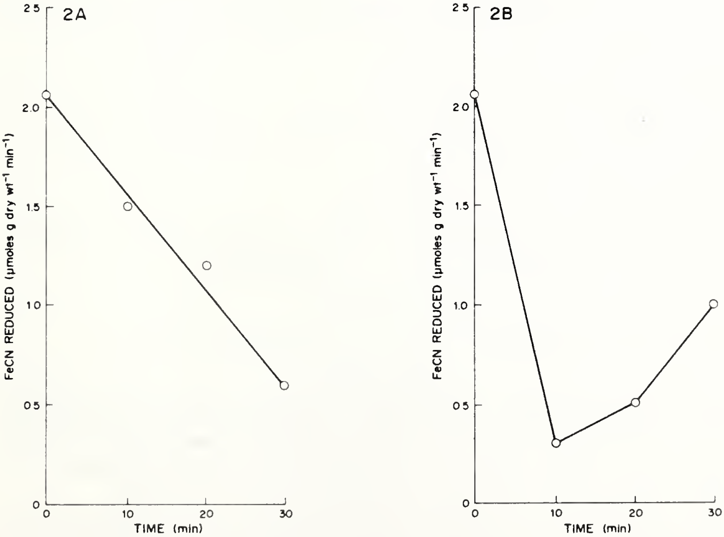
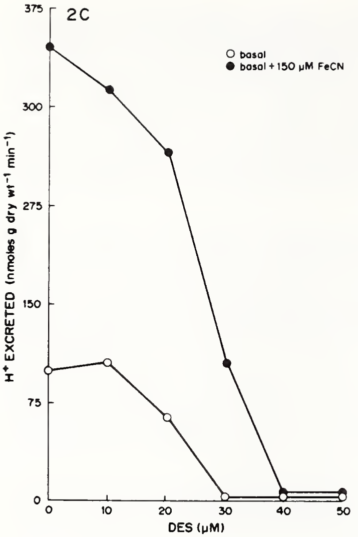


Figure 2A. The Effect of Incubating Cultured Carrot Cells with Diethyl Stilbestrol (100 μM) on Transmembrane Ferricyanide Reduction. The control rate was 2.06 μmoles FeCN reduced g dry wt.$^{-1}$ min^{-1}.

Figure 2B. The Effect of Incubating Cultured Carrot Cells with Dicyclocarbodiimide (100 μM) on Transmembrane Ferricyanide Reduction. The control rate was 2.06 μmoles FeCN reduced g dry wt.$^{-1}$ min^{-1}.



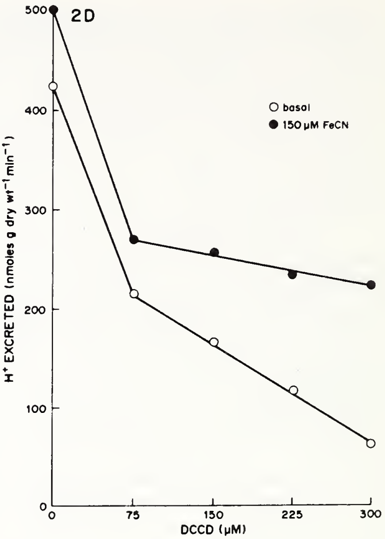


FIGURE 2C. The Effect of Diethyl Stilbestrol on H^+ Excretion by Cultured Carrot Cells. The basal rate of H^+ excretion was 101 nmoles H^+ excreted mg dry wt.$^{-1}$ min^{-1}; the rate with FeCN was 345.

FIGURE 2D. The Effect of Dicyclocarbodiimide on H^+ Excretion by Cultured Carrot Cells. The basal rate of H^+ excretion was 422 nmoles mg dry wt.$^{-1}$ min^{-1}; the rate with FeCN was 500.

conditions and the age of carrot cells. A study of factors which affect H^+ excretion during development is still in progress.

Abbreviations

DCCD, dicyclohexylcarbodiimide; DES, diethystilbestrol; HOQNO, 2-heptyl-4-hydroxyquinoline-N-oxide; KCN, potassium cyanide.

Acknowledgments

This study was supported by N.I.H. Grant PO1 36761 (F.L.C.).

Literature Cited

1. Böttger, M. and H. Lüthen. 1986. Possible linkage between NADH oxidation and proton secretion in *Zea mays* L. roots. J. Exper. Bot. 178, 666-675.
2. Craig, T.A. and F.L. Crane. 1981. Evidence for a trans-plasma membrane electron transport system in plant cells. Indiana Acad. Sci. 90, 150-155.
3. Craig, T.A. and F.L. Crane. 1982. Hormonal control of a transplasma membrane electron transport system in plant cells. Indiana Acad. Sci. 91, 150-154.
4. Crane, F.L., I.L. Sun, M.G. Clark, C. Grebing and H. Löw. 1985. Transplasma-membrane redox systems in growth and development. Biochim. Biophys. Acta 811, 233-264.
5. Federico, R. and C.E. Giartosio. 1983. A trans-plasma membrane electron transport system in maize roots. Plant Physiol. 73, 182-184.
6. Ivankina, N.G. and V.A. Novak. 1980. H^+-transport across plasmalemma.

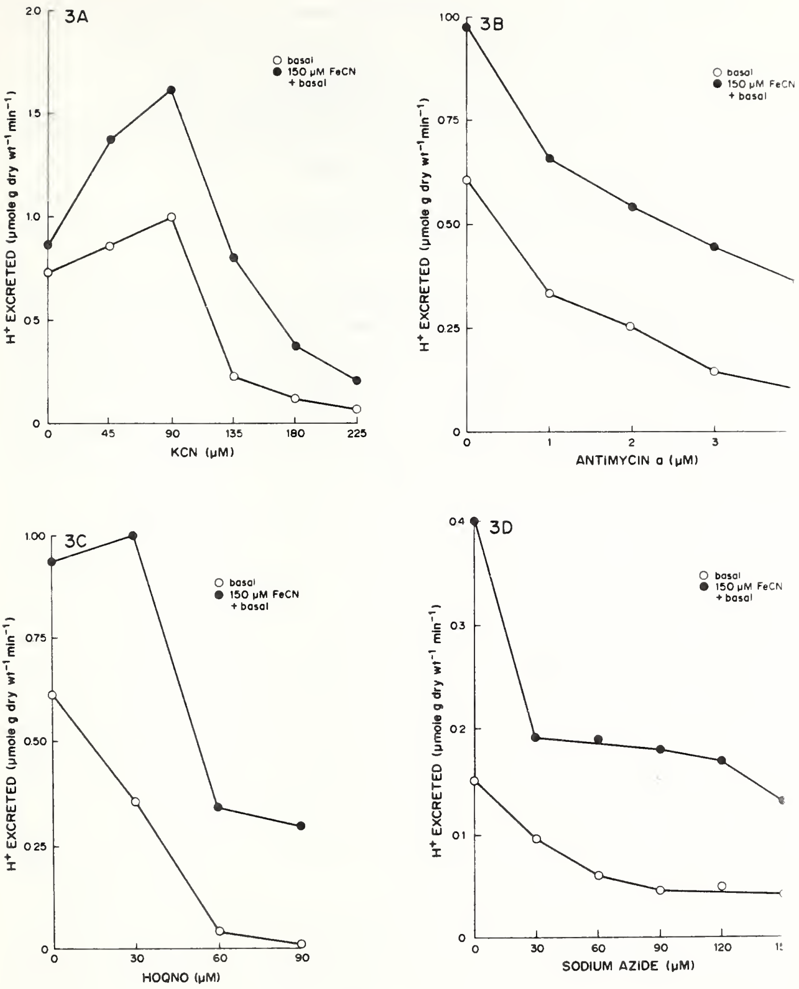


FIGURE 3. The Effect of Mitochondria Electron Transport Inhibitors on H$^+$ Excreti by Cultured Carrot Cells. A — KCN in concentrations indicated; B — antimycin a; — HOQNO; D — sodium azide. The assay conditions were as described in **Materi and Methods**. Note relative lack of inhibition of the ferricyanide-induced increment proton release, especially with antimycin a.

H$^+$-ATPase or redox-chain? In Plant Membrane Transport: Current Conceptu Issues (R.M. Spanswick, W.J. Lucas and J. Dainty, eds.), Elsevier, North-Holla Biomedical Press, Amsterdam, pp. 503-504.

7. Lin, W. and I.M. Møller. 1986. Membrane-bound NAD(P)H dehydrogenases higher plant cells. Ann. Rev. Plant Physiol. 37, 309-334.

8. Lüttge, U. and D.T. Clarkson. 1985. Mineral nutrition: plasmalemma and tonopl redox activities. Progress in Botany, vol. 47, Springer-Verlag, Berlin, pp. 73-

9. Marre, E. and A. Ballarin-Denti. 1985. The proton pumps of the plasmalemma and the tonoplast of higher plants. J. Bioenerg. Biomembr. 17, 1-21.
10. Murashige, T. and F. Skoog. 1962. A revised medium for rapid growth and bio assays with tobacco tissue cultures. Physiol. Plant. 15, 473-497.
11. Qui, Z.-S., B. Rubinstein and A.I. Stern. 1985. Evidence for electron transport across the plasma membrane of *Zea mays* root cells. Planta 165, 383-391.
12. Rubinstein, B., A.I. Stern and R.G. Stout. 1984. Redox activity at the surface of oat root cells. Plant Physiol. 76, 386-391.
13. Serrano, R. 1985. Membrane ATPase of Plants and Fungi. CRC Press, Boca Raton, Florida, pp. 80-129.
14. Sijmons, P.C., F.C. Lanfermeijer, A.H. de Boer, H.B.A. Prins and H.F. Bienfait. 1984. Depolarization of cell membrane potential during trans-plasma membrane electron transfer to extracellular electron acceptors in iron-deficient roots of *Phaseolus vulgaris* L. Plant Physiol. 76, 943-946.
15. Sze, H. 1985. H^+-translocating ATPases: advances using membrane vesicles. Ann. Rev. Plant Physiol. 36, 175-208.
16. Thom, M. and A. Maretzki. 1985. Evidence for a plasmalemma redox system in sugarcane. Plant Physiol. 77, 873-876.

Symptomatic Therapy for Demyelinating Diseases: The Role of Basic Science

Charles L. Schauf
Indiana University-Purdue University at Indianapolis
Indianapolis, Indiana 46223
and
Floyd A. Davis
Rush University
Chicago, Illinois 60612

Introduction

Aberrant impulse conduction in demyelinated axons in the central nervous system cause symptoms typical of multiple sclerosis (MS) and related diseases including blind spots (scotomas); loss of motor control; absence of sensation; and parethesias ("tinglings"). Conduction block is the major reason for loss of function (44); while paresthesias arise from an increased excitability of demyelinated, conducting fibers (27). The pathophysiology of demyelinating disease can be understood in terms of the conduction safety factor, defined as the ratio of the current generated during an action potential to the minimum (threshold) amount needed to maintain conduction. A normal safety factor is 6-7 and conduction block occurs if it falls below 1. Local anesthetics inhibit pain by reducing action potentials (and safety factor); while in MS there is short-circuiting of current in demyelinated nerves.

In MS frequent, spontaneous exacerbations (new symptoms and/or worsening of existing ones) and remissions occur because demyelinated fibers are delicately balanced with conduction safety factors near one (44). Conduction block takes place if an event (such as inflammation) decreases safety factor; while conduction is restored when the safety factor increases. Many patients (60-80%) are strikingly sensitive to small changes in body temperature. Fever causes a worsening similar to natural exacerbations and cooling results in improvement (33,36,46,55). Temperature-sensitivity arises because heating shortens action potentials and blocks borderline fibers; while cooling lengthens action potentials and can restore conduction in blocked fibers (12,39,40,41,44). The effect of cooling suggests that the symptoms of MS might also be relieved by drugs that increase the conduction safety factor.

Mathematical simulations were used to understand how temperature, calcium, and drugs affect conduction in MS (44). Normal nerve models (11,17,20) were modified to describe demyelination by altering the cable properties for a single fiber (29,47). Temperature effects were calculated by scaling ion channel rate constants by known amounts (18,22), while the action of calcium was obtained from the Ca^{++}-dependence of the same rate constants. The results agreed with observations on normal and demyelinated nerve fibers (3,12,13,38,41). For example, reducing calcium decreases threshold, increases the safety factor and causes transient improvements in MS (13).

There are many K^+ channels (15,16,17,18). The "classical" K+ channel identified by Hodgkin and Huxley (22) in found at nodes in nonmammalian myelinated nerves. In normal mammalian fibers, these K+ channels are excluded from nodes and the action potential is insensitive to K+ channel blockers (7,8,26). Potassium channels in the paranodes and internodes of mammalian nerve are exposed in demyelination, rendering them sensitive to K+ channel blockers (8,9.10,26,42,43,49). Impulses in developing and regenerated fibers are prolonged by K+ channel blockers (27,28,42,57). However, this does not localize K+ channels to nodes, it only shows they contribute to a nerve impulse. For example, mammalian and nonmammalian myelinated fibers may differ in the electrical or chemical accessibility of paranodal and internodal K+ channels.

In addition to cooling and lowering calcium, mathematical simulations indicated conduction in demyelinated nerve could be improved pharmacologically by blocking K+ *channels and by slowing closing (inactivation) of Na+* channels, because both prolong action potentials and increase safety factor (44). For example, the K+ channel blocker tetraethylammonium (TEA), should restore conduction. In animals TEA causes improvement (5,6,38), but it cannot be used in MS because of its side effects. The drug 4-aminopyridine (4-AP) also blocks nodal K+ channels and restores conduction in demyelinated animal models (5,6,14,16,25,26,38,40,45,51). Since 4-AP is used to treat myasthenia (30,31,32), it was natural to study its effect in MS.

Patients improve within minutes after receiving low does of 4-AP (23,50). The reason 4-AP affects demyelinated nerve fibers is that paranodal and internodal K+ channels are exposed and are 4-AP sensitive. However, the plasma levels of 4-AP may be as low as 1 μM in MS patients and micromolar amounts of 4-AP do not affect K+ channels in nonmammalian nerve fibers (16,25). The beneficial effect of 4-AP in mammalian systems would be expected if paranodal and internodal K+ channels were more sensitive than nodal channels. To compare nodal and non-nodal K+ channels one needs to study both populations in one fiber because K+ currents vary and 4-AP access may differ. In frogs the density of nodal and paranodal K+ channels depends on diameter (49). Large fibers have nodal K+ channels and the exposure of the paranode by demyelinating agents does not produce much of a change in K+ current. Small fibers lack nodal K+ channels, so that K+ currents are only seen following LPC demyelination. We took advantage of this size-dependence to show that the paranodal and internodal K+ channels exposed by demyelination are more sensitive to 4-AP than K+ channels present at the nodes.

Methods

Studies of Single Nerve Fibers

Frog fibers 8-10 μM in diameter (small) or 16-18 μM (large) were voltage-clamped by standard techniques (15,37,49). The external solution contained 115 mM NaCl, 2.5 mM KCl, 1.8 mM $CaCl_2$, and 5 mM Tris (pH of 7.30; 18-20 °C). Fibers were held at -80 mV and depolarized to voltages between -40 mV and $+100$ mV. Currents were recorded digitally and converted to conductances. Tetrodotoxin (1 μM) was used to reversibly block Na+ currents when K+ channels were being studied. Internodal resistance, resistance of the vaseline seals, nodal leakage current, nodal capacity, and the Na+ equilibrium potential were frequently measured. Continuous monitoring is important because internodal resistance gives membrane current; nodal capacitance indicates the nodal area; and internal Na+ can block K+ channels.

In untreated large and small fibers the capacity transient is exponential. To disrupt the paranode and expose paranodal and internodal K+ channels 1% lysolecithin (LPC) was applied for 1-2 minutes (49). Following LPC treatment the capacity transient had fast and slow components. The time constant (40-60 μsec) of the fast component was the same as prior to LPC, while the slow component had a time constant of 1 msec becaue the paranodal capacitance is being charged via a large series resistance. The integral of the slow component varied depending on the paranodal membrane exposed. Untreated large fibers had a nodal capacity of 1.4-1.6 pF and a nodal resistance of 34-46 megohms. Treatment with LPC elevated the capacitance (up to 55 pF); by an amount that depended on fiber diameter (49) but did not change the magnitude or time course of the Na+ current. In most cases LPC increased the nodal capacitance without any visible change, suggesting that LPC can disrupt the paranodal junction.

Animal Models of Demyelination

In peripheral nerve fibers the immediate reaction to a breach of the perineural sheath is herniation of the underlying fibers. Nerve fibers in this "perineural window" demyelinate in 3-6 weeks and later remyelinate (37). Demyelinated nerve trunks can be removed and mounted in a recording chamber to measure the number of conducting fibers (37). If the temperature of the recording pool is increased, many borderline conducting fibers are blocked, reducing the size of the compound action potential. If one subsequently applies drugs to the recording pool, any increase in amplitude of the compound action potential indicates restoration of conduction. This sytem is a sensitive way to determine the effect of pharmacological agents.

Clinical Studies of 4-Aminopyridine

Since hyperthermia reversibly blocks borderline-conducting demyelinated nerve fibers, temperature-sensitive MS patients are most likely to respond to drugs. Patients with thermally labile neurological deficits were selected using a water bath or a temperature controlled NASA astronaut space suit. Elevation of body temperature to 100-102 °F was sufficient to bring out latent signs. Paients also met the following criteria: (a) definite diagnosis of MS, (b) males not older 47, and (c) no history of other disease. Visual function, neurological exams, and vital signs (temperature, blood pressure, pulse, respiration, EKG, blood chemistries, and urine analysis) were monitored before; at intervals during administration of 4-AP or placebo; and until any changes observed reversed to pre-treatment levels.

Visual acuity, visual fields, and critical flicker fusion (CFF) were monitored. To measure acuity, two lines 0.14 minutes in width were displayed on an oscilloscope screen 0.3-3.0 meters from the patient, depending on the severity of the baseline visual impairment. The lines were initially superimposed and separated at constant velocity until a patient signaled two lines. The angular separation between the lines indicates acuity and the results of 5 trials were averaged for each eye. Central visual fields were monitored with the Goldman Perimeter. A light turned ON and OFF at low frequency is perceived as flickering. As frequency increases, a point is reached where the flicker disappears and a steady light is seen (the CFF). Five trials were averaged for each eye. Neurological exams were videotaped to qualitatively assess a broad spectrum of function. Non-visual neurological symptoms were rated on a scale of 0-6 with grade 0 representing normal performance and grade 6 a deficit so severe that the function was nearly or completely absent (e.g., inability to walk). Changes of two or more grades were considered significant, but improvement was only noted if the change in neurological function reversed.

The study was blinded for the patient. The neurologist administering 4-AP was not blinded to ensure appropriate management of adverse reactions. However, the overall evaluation of 4-AP was blinded because a technician not knowing if 4-AP was given obtained data on visual function; while the videotaped neurological exams were evaluated by a neurologist unaware of whether drug of placebo had been administered.

Results

Restoration of Impulse Conduction by 4-AP in Demyelinated Nerve

Figure 1 illustrates the compound action potential recorded from demyelinated frog sciatic nerves and is similar to results previously reported (38). Trace A was obtained at 25 °C and B at 28 °C. The integral of trace B is 22% of the integral of trace A, suggesting that 80% of the fibers are blocked by a 3 °C temperature elevation. Trace C was obtained 5 minutes after the application of 0.5 mM 4-AP to the recording pool and indicates a nearly complete restoration of conduction to the blocked fibers. Several other drugs were tested. Those increasing the amplitude of the compound action potential were

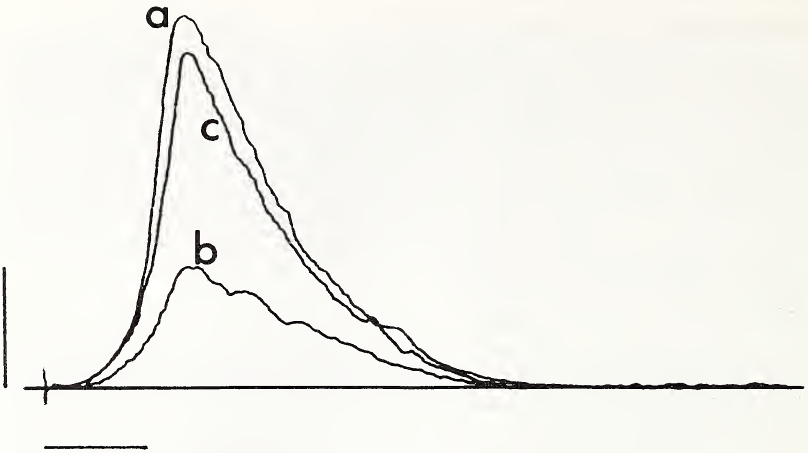


FIGURE 1. Compound action potentials in a frog sciatic nerve 26 days following perineural window-induced demyelination. Trace A was obtained at 25 °C and trace B at 28 °C in normal Ringer's solution. Trace C shows the compound action potential 5 minutes after adding 0.5 mM 4-AP to the recording pool. Voltage and time calibrations are 50 uV and 1.0 msec respectively.

the K+ channel blockers tetraethylammonium (TEA) and gallamine; and three inhibitors of Na+ inactivation including scorpion venom, n-bromoacetamide, and amantadine. The first four compounds have been investigated previously (6,38,41,48). Amantadine is primarily an antiviral drug, but is also used to treat Parkinson's disease. Studies (in progress) of voltage-clamped *Myxicola* giant axons have demonstrated that amantadine selectively slows Na+ inactivation, particularly at negative membrane potentials.

Differential Effects of 4-AP on Nodal and Paranodal K+ Channels

Three classes of frog myelinated nerve fibers were examined: (1) small fibers that normally lack K+ currents, but where large K+ currents can be induced by LPC, (2) large fibers in which LPC produces no more than a 10% increase in K+ current, and (3) intermediate-sized fibers where LPC treatment can double the amount of K+ current. Figure 2 shows that 4-AP selectively blocks the paranodal K+ channels exposed by LPC in small fibers. The left-hand records were obtained from untreated large (top) and small (bottom) fibers with Na+ equilibrium potentials of +52 mV and +54 mV respectively. Large fibers had a K+ conductance which averaged 30% of the Na+ conductance, while small fibers had only inward Na+ currents.

In large fibers, application of 20 μM 4-AP decreased the K+ current by 45-50% at all voltages, but did not affect the nodal Na+ current (top center records in Figure 2). At 1 mM, 4-AP completely eliminated the K+ current, again without altering the Na+ current (or the nodal capacitance, internodal resistance, or Na+ equilibrium potential). The filled circles in Figure 3 show the dose-response curve for 4-AP obtained in separate experiments on two large fibers. The solid line was calculated assuming a single 4-AP binding site with a dissociation constant of 20 μM and provides an adequate fit over the entire concentration range tested.

Treatment with LPC causes a large increase in the K+ current in small fibers without any change in the Na+ current or Na+ equilibrium potential (bottom center records in Figure 2). These LPC-induced K+ currents were associated with a 14-fold increase

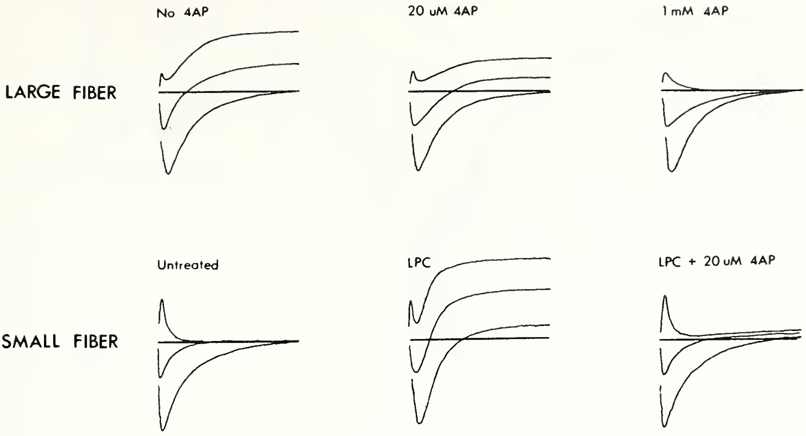


Figure 2. The effect of 4-AP on currents at single nodes of Ranvier for depolarizations to −30 mV, +20 mV, and +70 mV in normal and lysolecithin (LPC) treated fibers. The records in the upper portion of the Figure were from a 17 μM fiber, while those at the bottom were from a 9 μM fiber. The large fiber has a 4-AP sensitive K+ current (top center and right-hand records). Untreated small fibers lack K+ currents (lower left-hand record), but K+ currents appear following LPC (lower center). The LPC-induced K+ currents are completely blocked by 20 μM 4-AP (lower right), while the same concentration of 4-AP only produces a 50% inhibition of nodal K+ currents in untreated large fibers (top center records). The current calibration is 16 nA for the large fiber and 8 nA for the small fiber. The time scale is 2 msec for both.

in the nodal capacitance measured by integrating the area under the total capacity current (fast and slow components). In LPC-treated small fibers, 20 μM 4-AP completely eliminated the K+ current (bottom right records in Figure 2) and the dose response curve for two different small fibers is shown by the open circles in Figure 3. The behavior of these fibers is consistent with a decrease in the 4-AP dissociation constant from 20 μM to 4-5 μM, so that paranodal K+ channels exposed by LPC are 4-5 times more sensitive to 4-AP than are nodal K+ channels. Although the sensitivity to 4-AP differs, both nodal and paranodal K+ channels have a similar voltage- and time-dependent activation (not illustrated).

While paranodal K+ channels are preferentially blocked by 4-AP, they are less sensitive to TEA. Figure 4 shows that the dissociation constant for TEA on K+ channels in large fibers (filled circles and the solid line) is 0.5 mM, while that for paranodal K+ channels in small fibers is 5.0 mM. A decreased sensitivity of non-nodal K+ channels to TEA has previously been attributed to limited drug access (7,8,9,10). However, the fact that paranodal channels are more sensitive to 4-AP suggests that the differential response to TEA may also be real.

In a few experiments 4-AP and TEA were applied to intermediate-sized fibers. Untreated 12-14 μM fibers had resting K+ conductances of 0.10-0.15 $\times$ 10^{-7} S and we the dissociation constants for 4-AP and TEA were 20 μM and 0.5 mM respectively, identical to those in large fibers. When LPS was applied to intermediate fibers the K+ conductance increased to 0.22-0.31 $\times$ 10^{-7} S, but there was no change in Na+ currents. The dissociation constant for 4-AP on the LPC-induced incremental K+ conductance was 4 μM, while that for TEA was 3-5 mM. Paranodal K+ channels in intermediate

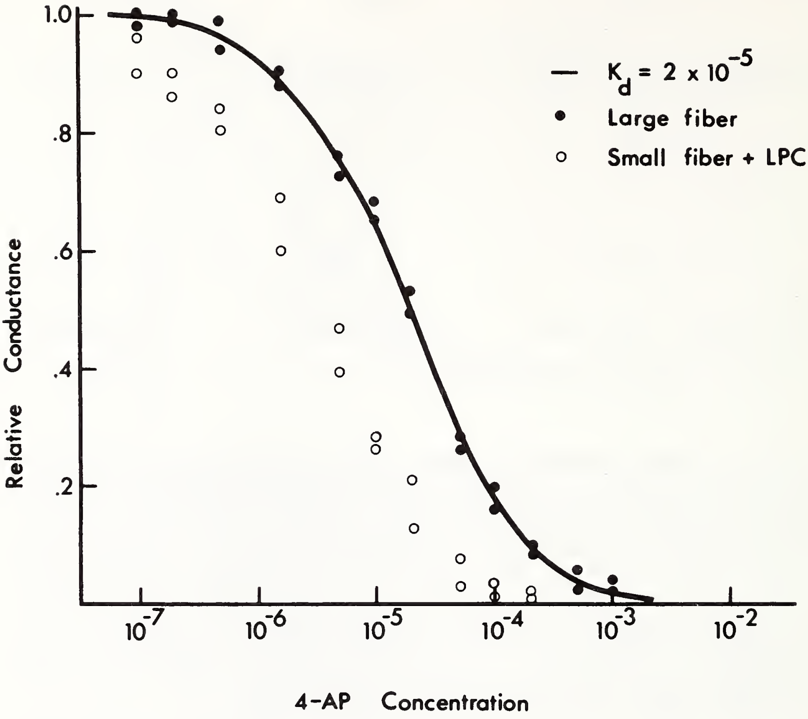


FIGURE 3. Dose-response curves for 4-AP in two different large (filled circles) and small (open circles) fibers. The ordinate is the K+ conductance in the presence of 4-AP relative to that prior to drug application. The solid line was calculated assuming a single binding site with a dissociation constant of 20 μM.

fibers thus resemble those in small fibers, while nodal channels have the same pharmacological specificity as nodal K+ channels in large fibers.

Effects of 4-AP in Multiple Sclerosis

In the clinical studies 4-AP was given intravenously (7-35 mg in 1-5 mg doses every 10-60 minutes over 1.5-3.5 hours) to 12 temperature-sensitive male MS patients and 5 normal men; and orally (5 mg capsules in divided doses to a total of 10-25 mg) to 9 MS patients and 6 normal controls. Nine additional male MS patients comprised a blinded control group receiving 0.9% NaCl intravenously or oral placebo. No changes occurred in vital signs, ECG, or EEG in any of the 33 individuals studied. All subjects who received 4-AP had transient peri-oral paresthesias, while those receiving placebo had no symptoms. In subjects receiving 4-AP mild dizziness sometimes occurred at 30-35 mg. This reversed 60 to 90 minutes after discontinuing 4-AP, but no subject received additional 4-AP if such symptoms developed.

Ten of 12 MS patients receiving intravenous 4-AP mildly to markedly improved ($X^2 = 10.12$; $P < 0.002$). Vision improved in 7 ($X^2 = 8.57$; $P < 0.0004$), oculomotor functions in 5 ($X^2 = 5.08$; $P < 0.024$), and motor function in 5 patients ($X^2 = 5.08$; $P < 0.024$). The improvements developed at doses as low as 2 mg and reversed 2-4 hours following the last dose. In the oral studies all 9 patients improved. No changes were seen

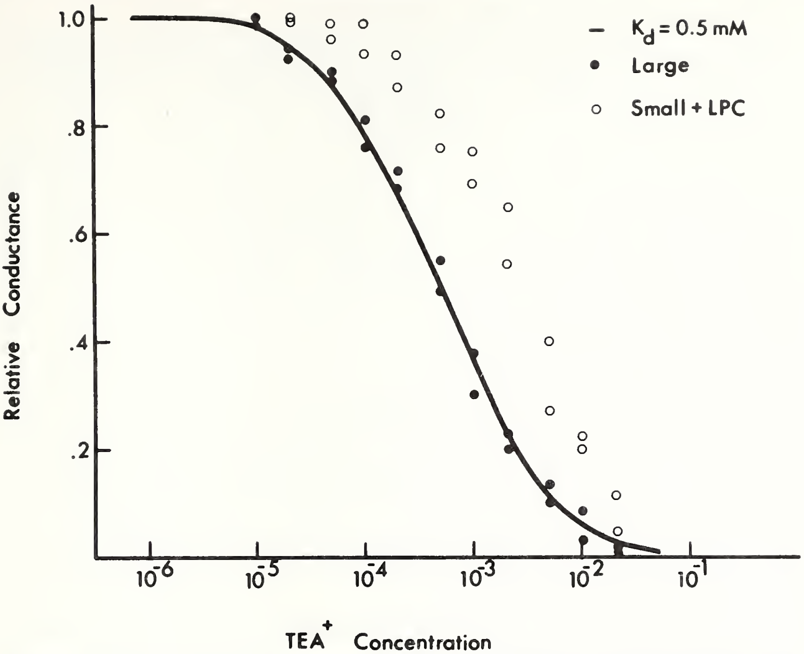


Figure 4. Dose-response curves for tetraethylammonium (TEA) in two large (filled circles) and small (open circles) fibers. The ordinate is the K+ conductance in the presence of TEA relative to that prior to drug application. The solid line was calculated assuming a single binding site with a dissociation constant of 0.5 mM.

in the MS patients receiving placebo. Table 1 summarizes the results of 4-AP administration. Blank spaces indicate a neurological function was not tested, either because it was normal or was not temperature-sensitive.

Figure 5 shows the effect of 4-AP on gait and visual signs. Improvement of gait (part A) began within 25 minutes after 4-AP at a dose of 2 mg and peaked at 65 minutes at a total dose of 5 mg. Reversal occurred gradually and was complete 2 hours and 40 minutes after the last dose. In MS patients CFF frequency is typically lower than the normal frequency of 40-50/sec. In another patient CFF frequency was 22/sec before 4-AP administration. After 10 mg of 4-AP, CFF rose to 45/sec and the effect gradually reversed to baseline 4 hours, 45 minutes after peak improvement. Static quantitative perimetry showed a similar improvement of visual fields (not illustrated). Before 4-AP the patient had a large central blind spot, but 25 minutes after receiving 15 mg of 4-AP the visual fields were nearly normal. The improvement was transient and the scotoma redeveloped 2 hours and 30 minutes later.

Discussion

Administration of 4-AP improves conduction in experimentally demyelinated nerve fibers in animals, while in MS patients it enhances vision, oculomotor, and motor function without serious side effects. The clinical improvements were great enough to represent a functionally significant therapy and the acute protocol used eliminates uncertainties caused by spontaneous fluctuations in the severity of symptoms in MS. The kinetics

TABLE 1. Results of 4-Aminopyridine Administration

Patient	Vision	Oculomotor	Motor	Net Effect
		Intravenous 4-AP		
1	3+	1+	0	Y
2	1+	2+		Y
3	2+		0	Y
4		3+	2+	Y
5			3+	Y
6		0	0	N
7	2+	3+	3+	Y
8	2+			Y
9	0	1+	3+	Y
10	0		0	N
11	2+			Y
12	2+		1+	Y
		Oral 4-AP		
1	2+	2+	1+	Y
2	3+	2+		Y
3	1+	1+	1+	Y
4		2+	3+	Y
5			2+	Y
6		2+	2+	Y
7	3+	1+	2+	Y
8	1+	2+		Y
9	1+	1+	3+	Y

1+ = mild improvement
2+ = moderate improvement
3+ = marked improvement
0 = no improvement
Y = positive effect
N = without effect

of 4-AP have been studied in normal subjects at serum levels of 40 μg/L (53). The half-life of 3.6 ± 0.9 hours corresponds to the duration of the improvements observed. Studies of myasthenia show 4-AP affects synapses (31,31,32). Synaptic effects probably do not cause improvements in MS because no changes in motor function in normals were seen, and enhancement of vision strongly supports a direct action of 4-AP on demyelinated optic nerves. In experimental lesions 4-AP causes repetitive firing (27). Seizures can be triggered by ectopic activity in axons (21, so MS patients might be at higher risk than normals.

Clinical changes produced by 4-AP most likely are the result of restoration of conduction in blocked demyelinated nerve fibers. Where does 4-AP act and why is it effective at low doses? The results of LPC-treatment in frog fibers provide answers to both questions. Potassium channels are absent from normal mammalian nodes and small frog fibers, but are present in the paranode and internode and become exposed in demyelination (7,8,9,10,26,51). Since 4-AP only affects K+ channels, it must act on demyelinated axons. However, theoretical simulations suggest the crucial safety factor decrease occurs at the junction between the normal region of a myelinated fiber and a demyelinated segment (40,56,57,58,60). If 4-AP were restoring conduction here, it would be doing so by acting at the last normal node. Since normal nodes do not contain K+ channels, an effect of 4-AP would require some change that would expose paranodal K+ channels, such as a loosening of the myelin seal.

Paranodal K+ channels have a four-fold lower dissociation constant for 4-AP than nodal K+ channels. If internodal K+ channels are similar, then 4-AP should preferen-

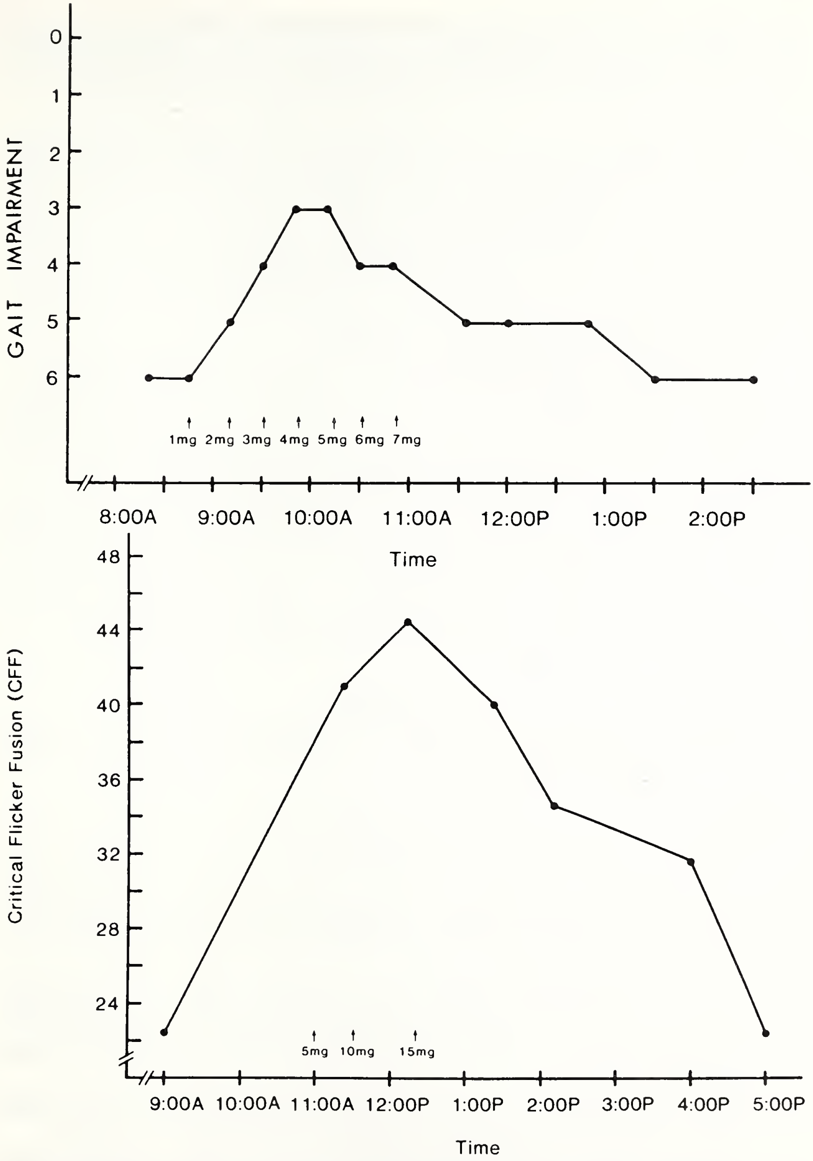


FIGURE 5. Part A illustrates the effect of intraveneous 4-AP on gait in a 43 year old MS patient. Gait is rated on a scale of 0 to 6 with 0 representing normal function and 6 severe impairment. Administration of 4-AP is noted by the arrows and dosages on the abcissa. Note that the improvement produced by 4-AP is transient and returns to baseline levels after cessation of 4-AP therapy. Part B shows the effect of 4-AP on critical flicker fusion (CFF) frequency in a second, 46 year old patient. Again, the administration of 4-AP is noted by the arrows and dosages on the abcissa and the improvement produced by 4-AP is transient.

tially affect demyelinated nerve. The K+ channel in nonmyelinated fibers and at synapses resemble nodal K+ channels in terms of their 4-AP sensitivity, providing a rationale for the lack of significant side effects at dosages sufficient to restore functional capacity in MS patients.

Several derivatives of 4-AP are potent K+ channel blockers. For example, 3,4-diaminopyridine (3,4 DAP) has a dissociation constant of 6 μM in squid axons (24). In two large frog fibers 5 μM 3,4 DAP reduced the K+ current by 60-70%, consistent with a 5-6 fold lower dissociation constant for 3,4 DAP compared to 4-AP. In two LPC-treated small fibers 5 μM 3,4 DAP eliminated the K+ current. Thus a similar differential sensitivity of nodal and paranodal channels seems to hold for 4-AP derivatives. In myasthenia, 3-4 DAP has fewer side effects (32), perhaps because it traverses the blood brain barrier less rapidly. If so, 3,4 DAP offers the advantage of acting more selectively than 4-AP at MS lesions and should be investigated.

Other drugs need to be examined in the same way as 4-AP. Gallamine blocks K+ channels (48) and has a low blood-brain barrier permeability. As a neuromuscular blocking agent in surgery, gallamine is injected at a dose of 1 mg/kg. In unanesthetized subjects 0.7 mg/kg gives minimal surgical relaxation (54) and at this dose a plasma level of 3μM would be expected. In frog myelinated nerve there is a 10% block of K+ conductance with 10 μM gallamine (48), so significant K+ conductance changes might occur in man. There are also threshold-lowering agents. For example, WR-2721 produces hypocalcemia by inhibiting parathyroid secretion and calcium release from bone (1,19) and should have the same therapeutic effects as oral phosphate (13). A combined administration of a threshold-lowering agent and a K+ channel blocker would be an optimal way to produce a maximal increase in conduction safety factor with the least side effect.

Acknowledgment

Supported by National Multiple Sclerosis Society Grant RG 1911A4 and National Science Foundation Grant BNS 86-96095.

Literature Cited

1. Attie, M.F., Fallon, M.D., Spar, B., WOlf J.S., Statopolsk, E., Goldfarb, S.: Bone and parathyroid inhibitory effects of S-2 (3-aminopropylamino) ethylphosphorothioic acid. Studies in experimental animals and cultured bone cells. J. Clin. Invest. 75: 1191-1197, 1985.
2. Ball, A.P., Hopkinson, I.D., Farrell, J.G.P., Hutchinson, R.P., Watson, A.J.F., Page, R.G.F., Parker, C.W., Edwards, M., SNow, D.K., Scott, A., Leone-Ganado, A., Hastings, A.C., Ghosch, A.C. and Gilbert, R.J.: Human botulism caused by Clostridium botulisum type E — The Birmingham outbreak. Quart. J. Med. 48:473-491, 1979.
3. Becker, F.D., Michael, J.A., Davis, F.A.: Acute effects of Oral phosphate on visual function in Multiple Sclerosis. Neurology 24:601-607, 1974.
4. Bostock, H., Sears, T.A.: The internodal axon membrane: Electrical excitation and continuous conduction in demyelination. J. PHysiol., 280:273-301, 1978.
5. Bostock, H., Sears, T.A., Sherratt, R.M.: The effects of 4-aminopyridine and tetraethylammonium ions on normal and demyelinated mammalian nerve. J. Physiol. 313:301-315, 1981.
6. Bostock, H., Sherratt, R.M., Sears, T.A.: Overcoming conduction failure in demyelinated nerve by prolonging action potentials. Nature, 274:385-387, 1978.
7. Brismar, T.: Specific permeability properties of rat demyelinated nerve fibers. Acta. Physiol. Scan. 113:167-176.

8. Chiu, S.Y., Ritchie, J.M.: Potassium channels in nodal and internodal axonal membrane of mammalian myelinated nerve fibers. Nature 284:170-171, 1980.
9. Chiu, S.Y., Ritchie, J.M.: Evidence for the presence of potassium channels in the paranodal region of acutely demyelinated mammalian myelinated nerve fibers. J. Physiol. 313:415-437, 1981.
10. Chiu, S.Y., Ritchie, J.M.: Evidence for the presence of potassium channels in the internode of frog myelinated nerve fibers. J. Physiol. 32: 485-501, 1982.
11. Cooley, J.W., Dodge, F.A.: Digital computer solutions for excitation and propagation of the nerve impulse. Biophys. J. 6:583-599, 1966.
12. Davis, F.A.: Axonal conduction studies based on temperature effects in multiple sclerosis. Electroenceph. Clin. Neurophysiol. 28:281-286, 1970.
13. Davis, F.A., Becker, F.O., Michael, J.A., Sorenson, E.: Effect of intravenous sodium bicarbonate, disodium edetae (Na_2EDTA), and hyperventilation of visual and oculomotor signs in MS. J. Neurol. Neurosurg. Psychiatry. 33:723-732, 1970.
14. Den Hertog, A., Pielkenrood, J., Biessels, P., Agoston, S.: The effect of some new aminopyridines on mammalian myelinated nerve fibers. Euro. J. Pharmacol. 94:353-355, 1983.
15. Dodge, F.A., Frankenhauser, B.: Membrane currents in isolated frog nerve fibers under voltage-clamp conditions. J. Physiol. 143: 76-90, 1968.
16. Duboi, F.: Properties and physiological roles of K+ currents in frog myelinated nerve fibers as revealed by 4-AP. Advances in Biosciences. 35: 43-51. Lechet, P., ed. Pergamon Press, New York, 1982.
17. Frankenhaeuser, B.: Computed action potential in nerve from Xenopus Laevis. J. Physiol. 180: 780-787, 1965.
18. Frankenhaeuser, B., Moore, L.E.: The effect of temperatue of the sodium and potassium permeability changes in myelinated nerve fibers of Xenopus Laevis. Journal of Physiology, 169, 431-437, 1963.
19. Glover, D., Riley, L., Carmichael, K., Spar, B., Glick, J., Kligerman, M.M., Agus, Z.S., Slatopolsky, E., Attie, M., Goldfarb, S.: Hypocalcemia and inhibition of parathyroid hormone secretion after administration of WR-2721 (A radioprotective and chemoprotective agent). N. Eng. J. Med. 309:1137-1141, 1983.
20. Goldman, L., Albus, J.A.: Computation of impulse conduction in myelinated fibres: theoretical basis of the velocity-diameter relation. Biophys. J. 8: 596-607, 1968.
21. Gutnick, M.J., Prince, D.A.: Thalamocortical relay neurons: Antidromic invasion of spikes from a cortical epileptogenic focus. Science 176:424-426, 1972.
22. Hodgkin, A., Huxley, A.F.: A quantitative description of membrane current and its applications to conduction and excitation in nerve. J. Physiol. 117: 500-544, 1952.
23. Jones, R.E., Heron, J.R., Foster, D.H., Snelgar, R.S., Mason, R.J.: Effects of 4-aminopyridine in patients with Multiple Sclerosis. J. Neurol. Sci. 60:353-362, 1983.
24. Kirsch, G.E., Narahashi, T.: 3,4-Diaminopyridine; a potent new potassium channel blocker. Biophys. J. 22:507, 1978.
25. Kirsch, G.E., Narahashi, T.: Site of action and active form of aminopyridine in squid axon membranes. J. Pharmacol. Exptl. Thera. 226:174-179, 1983.
26. Kocis, J.D.: Functional characteristics of potassium channels of normal and pathological mammalian axons. Ion Channels in Neural Membranes. Ritchie, Keynes, and Bolis eds. Alan Liss, New York, pp. 123-144, 1986.
27. Kocis, J.D., Bowe, C.M., Waxman, S.G.: Different efects of 4-aminopyridine on sensory and motor fibers: pathogenesis of paresthesias Neurology 36: 117-120, 1986.
28. Kocis, J.D., Waxman, S.G.: Long-term regenerated nerve fibers retain sensitivity to potassium channel blocking agents. Nature 304: 640-642, 1983.
29. Koles, Z.J., Rasminsky, M.: A computer simulation of conduction in demyelinated nerve fibres. J. Physiol. 227:351-364, 1972.

30. Lundh, H., Nilsson, O., Rosen, I.: 4-aminopyridine — a new drug tested in the treatment of Eaton-Lambert syndrome. J. Neurol. Neurosurg. Psychiat. 40: 1109-1112, 1977.
31. Lundh, H., Nilsson, O., Rosen, I.: Effects of 4- aminopyridine in myasthenia gravis. J. Neurol. Neurosurg. Psychiat., 42:171-175, 1979.
32. Lundh, H., Nilsson, O. and Rosen, I., Treatment of Lambert-Eaton Syndrome: 3,4-Diaminopyridine and pryidostigmine. Neurology, 34:1324-1330, 1984.
33. Malhotra, A.S., Goren, H.: The hot bath test in the diagnosis of Multiple Sclerosis. JAMA 246:1113-1114, 1981.
34. McDonald, W.I.: Effects of experimental demyelination on conduction in peripheral nerve: a historical and electrophysiological study. Brain 86:501-524, 1963.
35. McDonald, W.I., Sears, T.A.: The effects of experimental demyelination on conduction in the central nervous system. Brain 93:583-598, 1970.
36. Nelson, D.A., McDowell, F.: The effects of induced hyperthermia on patients with Multiple Sclerosis. J. Neuro. Neurosurg. Psychiat. 22:113-116, 1959.
37. Pencek, T.L., Schauf, C.L., Davis, F.A.: The effect of haloperidol on the ionic currents in the voltage-clamped node of Ranvier. J. Pharmacol. Exptl. Thera. 204: 400-408, 1978.
38. Pencek, T.L., Schauf, C.L., Low, P.A., Eisenberg, B., Davis, F.A.: Disruption fo the perineurium in amphibian peripheral nerve: Morphology and physiology. Neurology, 30:593-599, 1980.
39. Rasminsky, M.: The effects of temperature on conduction in demyelinated single nerve fibers. Arch. Neurol. 28:287-292, 1973.
40. Rasminsky, M. Physiology of conduction in demyelinated axons. In: Physiology and Pathobiology of Axons, edited by S.G. Waxman, oo, 361-376. Raven Press, New York, 1978.
41. Rasminsky, M., Sears, T.A.: Internodal conduction in undisected demyelinated nerve fibers. J. Physiol. 227:323-350, 1972.
42. Ritchie, J.M.: Sodium and potassium channels in regenerating and developing mammalian myelinated nerves. Proc. Roy. Soc. Lond. 215:273-287, 1982.
43. Ritchie, J.M., Rogart, R.B.: Density of sodium channels in mammalian myelinated nerve fibers and nature of the axonal membrane under the myelin sheath. Proc. Natl. Acad. Sci. USA. 74: 211-215, 1977.
44. Schauf, C.L., Davis, F.A.: Impulse conduction in Multiple Sclerosis: A theoretical basis for modification by temperature and pharmacological agents, J. Neurol. Neurosurg. Psychiat. 37:152-161, 1974.
45. Sherratt, R.M., Bostock, H., Searts, T.A.: Effects of 4-aminopyridine on normal and demyelinated mammalian nerve fibers. Nature, 283:570-571, 1980.
46. Simons, D.J.: Note on effect of heat and of cold upon certain symptoms of Multiple Sclerosis. Bull. Neurol. Inst. N.Y. 6:385-386, 1937.
47. Smith, R.S., Koles, Z.J.: Myelinated nerve fibres: computed effect of myelin thickness on conduction velocity. Amer. J. Physiol. 219: 1256-1258, 1970.
48. Smith, K.J., Schauf, C.L.: Effects of gallamine triethiodide on membrane currents in amphibian and mammalian peripheral nerve. J. Pharmacol. Exper. Ther. 217:719-726, 1981.
49. Smith, K.J., Schauf, C.L.: Size-dependent variation in nodal properties in myelinated nerve. Nature 293: 297-299, 1981.
50. Stefoski, D., Davis, F.A., Faut, M., Schuaf, C.L.: 4-aminopyridine improves clinical signs in multiple sclerosis. Ann. Neurol. (in press), 1986.
51. Targ, E.F., Kocsis, J.D.: 4-Aminopyridine leads to restoration of conduction in demyelinated rat sciatic nerve. Brain Res. 328:358-361, 1985.

52. Targ, E.F., Kocsis, J.D.: Action potential characteristics of demyelinated rat sciatic nerve following application of 4-Aminopyridine. Brain Res. 363:1-9, 1986.
53. Uges, D.R.A., Sohn, Y.J., Greijdanus, B., Scaf, A.H.J., Agoston, S.: 4-Aminopyridine Kinetics. Clin. Pharmacol. Ther. 31:587-593, 1982.
54. Unna, K.R., Pelikan, E.: Evaluation of curarizing drugs in man. VI. Critique of experiments of unanesthetized subjects. Ann. N.Y. Acad. Sci., 54:480-490, 1951.
55. Watson, C.W.: Effect of lowering body temperature on the symptoms and signs of Multiple Sclerosis. N. Eng. J. Med. 261:1253-1259, 1959.
56. Waxman, S.G.: Prerequisites for conduction in demyelinatd fibers, Neurology, 28:27-33, 1978.
57. Waxman, S.G.: Membranes, myelin and the pathophysiology of Multiple Sclerosis. N. Eng. J. Med. 306:1529-1533, 1982.
58. Waxman, S.G., Brill, M.H.: Conduction through demyelinated plaques in multiple sclerosis, Computer simulations of facilitation by short internodes. J. Neurol. Neurosurg. Psychiatry, 41:408-416, 1978.
59. Waxman, S.G., Kocis, J.D., Eng D.L.: Ligature induced injured peripheral nerve: observations on changes in action potential characteristics following blockade of potassium conductance. Muscle and Nerve. 8:85-92, 1985.
60. Waxman, S.G., Wood, S.L.: Impulse conduction in inhomogeneous axons: effects of variation in voltage-sensitive ionic conductances on invasion of demyelinated axon segments and preterminal fibers. Brain Res. 294:111-122, 1984.
61. Yeh, J.Z., Oxford, G.S., Wu, C.H., Narahashi, T.: Dynamics of aminopyridine block of potassium channels in squid axon membrane. J. Gen. Physiol. 68: 519-535, 1976.

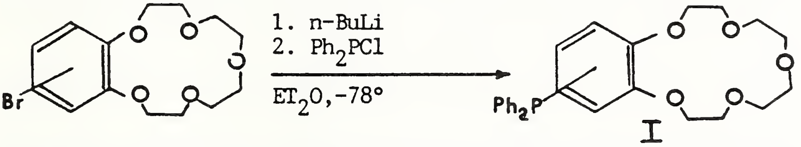
CHEMISTRY

Chair: Mohammad Behforouz
Department of Chemistry
Ball State University
Muncie, Indiana 47306 (317) 285-8070

Chair-Elect: Kenneth L. Busch
Department of Chemistry
Indiana University
Bloomington, Indiana 47405 (812) 335-2081

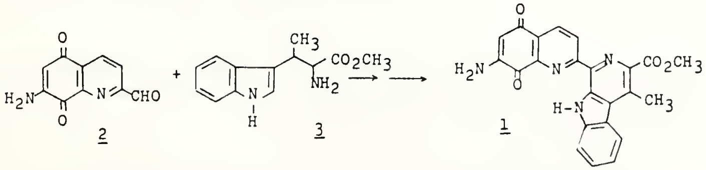
ABSTRACTS

Functionalized Crown Ethers: Benzo Crowns with P(III) Centers. John Bain, Vida Farazi and Bruce N. Storhoff, Ball State University, Muncie, Indiana 47306.——Spectroscopic evidence indicates that the diphenylphosphine derivative of benzo-15-crown-5 has been obtained *via* the reaction scheme shown below. Bromination of the parent crown was accomplished with either NBS or $Tl(OAc)_3/Br_2$ in CCl_4.



Evidence has been obtained which indicates that the P(III) center reacts as expected with metal centers. $(PhCN)_2PdCl_2$, for example, readily reacts with I to provide a yellow colored complex which has been assigned the stoichiometry *trans*-$(I)_2PdCl_2$.

Studies Toward the Total Synthesis of Lavendamycin Methyl Ester, an Antitumor Antibiotic Agent. Mohammad Behforouz, Hamideh Zarrinmayeh and Mark A. Horn, Ball State University, Muncie, Indiana, 47306.——The objective of our studies is the synthesis of 1 through the Pictet-Spengler condensation of aldehyde 2 with β-methyltryptophan methyl ester 3, followed by dehydrogenation. Model studies and preparation of intermediates will be described.



Applications of Chromatography/Secondary Ion Mass Spectrometry. Kenneth L. Busch, Department of Chemistry, Indiana University, Bloomington, Indiana 47405.——A secondary ion mass spectrometer can be used to directly analyze organic and inorganic mixtures separated by thin layer or paper chromatography, and biochemical mixtures separated by electrophoresis. A renewable sample surface is necessary to provide a stable and persistent beam of secondary ions. A phase transition matrix which is melted at the point of analysis is used to renew the surface. Spatially-resolved mass spectra are obtained when the chromatogram is moved through the point of instrument focus. The use of this spatially-resolved information for the determination of sample spot homogeneity will be discussed. Derivatization reactions can be used with chromatography/secondary ion mass spectrometry to provide information about the distribution of organic compounds of certain functional groups distributed within a chromatogram.

Atomic Spectroscopic and Neutron Activation Analyses of Trace Heavy Metals in Water Supplies Surrounding a Municipal Landfill. CHERYL A. BYE AND JAMES P. RYBARCZYK, Ball State University, Muncie, Indiana 47306.——The levels of 12 trace heavy metals (including toxic As, Pb, and Cd) were monitored at 20 wells and creed bed sites surrounding a closed municipal landfill. Samples were collected weekly over a 15-week period, and results will be reported as a function of geographic location, depth of sample, and rainfall amount.

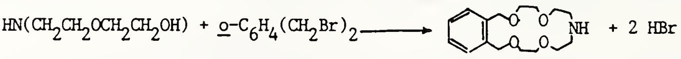
A combination of several spectroscopic and nuclear techniques were utilized for the analyses, each with their own strengths and interferences. Elements in relatively high concentration were determined by simple flame AA and flame emmission. Low concentration metals were measured by graphite furnace AA and ICP, which also were utilized to verify the flame data after dilution to lower concentrations. Further verifications of these concentration levels were provided by nuclear spectroscopic neutron activation analysis after a 400:1 preconcentration step.

Interaction of Some Metals and Tetrathionate Ions. S.W. DHAWALE, Indiana University East, Richmond, Indiana 47374.——The corrosion of various metals and alloys is being studied in the presence of sulfur oxyanions.

The present investigation deals with the interaction of tetrathionate ions with iron powder and nickel plates. The corrosion of nickel was quite visible from the black film formed. Some results on the attempts to use spectroscopic techniques to identify the corrosion product on the metal surface will be presented. The initial results indicated the formation of thiosulfate ions during the corrosion. Results on the estimation of thiosulfate ions will be reported.

The Preparation of Functionalized Aza Crown Ethers. VIDA FARAZI, M. BRIAN ARNOLD AND BRUCE N. STORHOFF, Ball State University, Muncie, Indiana 47306.——Aza crown ether 1 with three types of metal-binding sites has been synthesized from commercially available starting material by using the following reaction scheme. Reactions of 1 with

$$H_2NCH_2CH_2OCH_2CH_2OH + ClCH_2CH_2OCH_2CH_2OH \longrightarrow HN(CH_2CH_2OCH_2CH_2OH)_2 + HCl$$



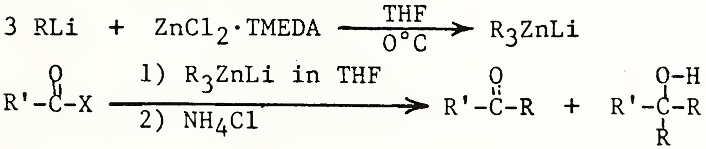
allylic and benzylic halides, such as p -$BrC_6H_4CH_2Br$, in the presence of sodium carbonate provided good yields of the corresponding derivatives. Strategies for functionalizing these crown ethers with P(III) centers will be discussed.

Potassium Ion Induced Enhancement of Crown Fluorescence by Displacement of a Complexed Quencher. SUSAN J. GANION, PAUL L. BOCK AND LYNN R. SOUSA, Ball State University, Muncie, Indiana 47306.——As a part of an effort to devise new types of potassium sensitive analytical reagents, a crown ether containing a fluorescent naphthalene chromophore has been synthesized and its fluroescence properties studied. In methanol solution, the presence of cesium ions causes a dramatic quenching (decreasing) of fluorescence due to a "heavy atom effect" by complexed cesium ions. When potassium ions are present in a solution containing crown ether and cesium ions, the potassium ions cause an increase in fluorescence by displacing the quenching cesium ions from the crown ether compound. Since the increase in fluorescence intensity is directly related to the concentration of potassium ion present, the crown ether-cesium ion system can be used to determine the concentration of potassium ions present in solution.

The data has been analyzed by a nonlinear least squares curve fitting program. This analysis and its relationship to the design of more sensitive crown ether fluorescent agents will be discussed.

Electron Spin Resonance of Membranes. Mary E. Huss, Department of Mathematics, Indiana University East, Richmond, Indiana 47374, Jerome I. Kaplan and Stephen R. Wassall, Department of Physics and William Stillwell, Department of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.——Detailed analysis of ESR (electron spin resonance) spectra recorded for spin labelled lipid molecules in membranes requires the formulation of a quantum mechanical model (spin density matrix) which allows for various kinds of molecular motion, thus enabling a comparison to be made of the experimental spectra with simulated spectra. A computer program will be described which gives the simulated spectra in terms of motional parameters (correlation times and order parameters). The effects of retinoid (vitamin A and derivatives) and fatty acid incorporation on ESR spectra for nitroxide spin labeled stearic acids intercalated into phospholipid model membranes will be discussed as examples of application of the program.

Reactions of Lithium Triorganozincates with Acid Halides. Richard A. Kjonaas and Douglas Sanquenetti, Indiana State University, Terre Haute, Indiana 47809.——Several lithium triorganozincates (R_3ZnLi) were prepared from zinc chloride/N,N,N′,N′-tetramethylethylenediamine complex ($ZnCl_2$•TMEDA) and organolithium reagents. These were then treated with acid halides under a variety of reaction conditions to give ketones and tertiary alcohols.



$$3\ RLi + ZnCl_2\cdot TMEDA \xrightarrow[0°C]{THF} R_3ZnLi$$

$$R'\text{-}\overset{O}{\overset{\|}{C}}\text{-}X \xrightarrow[2)\ NH_4Cl]{1)\ R_3ZnLi\ in\ THF} R'\text{-}\overset{O}{\overset{\|}{C}}\text{-}R + R'\text{-}\underset{R}{\overset{O\text{-}H}{C}}\text{-}R$$

R' = alkyl or aryl
X = F, Cl, Br

The method appears to complement existing methods of synthesizing ketones from acid haldies.

Electron Impact Mass Spectrometry of β-Alkylhydrocinnamate Methyl Esters. Terry L. Kruger, Timothy T. Curran and Mohammad Behforouz, Ball State University, Muncie, Indiana 47306.——The title compounds with alkyl = methyl-, ethyl-, isopropyl-, t-butyl- and vinyl- were subjected to mass spectrometric analysis. The fragmentation patterns were typical of β-aryl esters but still very sensitive to the nature of the alkyl group. The observed patterns arise from competition between (a) α-cleavage ($-OCH_3$), (b) McLafferty rearrangement (-74), and (c) ketene extrusion (-42). The effect of alhyl substituent on the predominant mode of reaction will be discussed.

Validation of a Test to Identify Erythro and Threo Diastereomers of RCHDCHDX Compounds: Variable-temperature NMR Studies of 2-Chloroethanol. David L. McCollum and Paul L. Bock, Ball State University, Muncie, Indiana 47306.——RCHDCHDX compounds have been used widely in determining the stereochemistry at carbon of organic and organometallic reactions. The use of these compounds has required the assumption that erythro diastereomers have larger vicinal coupling constants than threo diastereomers. We previously had proposed a test, based on variable temperature nmr, that should allow one to avoid making any assumptions about which coupling constant goes with which diastereomer. In that earlier work, theoretical considerations involving the Karplus equation and semiempirical molecular orbital calculations indicated that in a variable temperature nmr study, the coupling constants of erythro compounds should change about twice as fast as the coupling constants for threo compounds. This paper describes variable-temperature nmr studies of 2-chloroethanol. The "erythro" coupling constant changed 2.90 times as fast as the "threo" coupling constant. These results are in complete accord with our previously proposed test.

A Study of Adenosine Deaminase and Its Conversion Factor in Normal and Pathological Human Serum. Pang Fai Ma and Jeffrey T. Starkey, Center for Medical Education, Ball State University, Muncie, Indiana 47306.——A large and small molecular form of adenosine deaminase have been reported in advanced mammals, including man. The molecular weights of these enzyme forms are estimated to be 200,000 and 35,000 respectively by gel filtration column chromatography. The small form can be reversibly converted into the large form in the presence of conversion factor, a high molecular weight glycoprotein that is aggregated during this process. Previous studies have shown that the distribution of the two molecular forms of adenosine deaminase is tissue-specific (for instance, the large form of the enzyme is predominant in human liver while the small form is predominant in human heart). It follows that the conversion factor is present in higher amounts within those tissues where the large form predominates. With this in mind, an attempt is made to study the conversion process and determine whether or not the serum level of conversion factor is elevated in certain pathological conditions.

A Search for a Flashier Crown: Synthesis of a Crown Ether with Potassium Ion Enhanced Fluorescence. Thomas E. Mabry, C. David Whitesell and Lynn R. Sousa, Ball State University, Muncie, Indiana 47306.——The synthesis of a new and (we hope) more sensitive crown ether that will signal the presence of potassium ions by increased fluorescence will be described. In earlier work we have synthesized and studied crown ether compounds containing a fluorescent chromophore and a quenching group across from each other on the same crown ether ring. These crown ether compounds signal the presence of potassium ions in solution by giving more intense fluorescence. Evidently the complexation of potassium ions by the crown ether ring stiffens the molecule and separates the fluorescent chromophore from the quencher thus increasing fluorescence intensity.

Our new crown ether molecule has been designed with a cavity-size and ligand-number that should improve its ability to complex potassium ions over our earlier crown ether compounds. These design changes should enhance the sensitivity of the compound, but also make the synthesis somewhat more difficult.

Three-dimensional Profiling of Matrix-interferences in the ICP. John E. Sharkitt, Gregory A. Stephenson and James P. Rybarczyk, Ball State University, Muncie, Indiana 47306.——A FORTRAN program was developed to mathematically transform two-dimensional lateral emission data from an ICP source into 3-dimensional spatial data using the ABEL function. The experimental emission first had to be described by a curve-fitted mathematical formula, as performed by BMDP. This mathematical description of the lateral data was utilized by the ABEL program to produce three-dimensional radial profiles of the cylindrical ICP. The ABEL provides accurate spatial resolution of analyte atomic and emission processes.

These ABEL-resolved profiles were then utilized to describe the exact location of analyte-matrix interactions and excitations in the ICP. Easily ionized matrix elements cause spatially-controlled enhancement suppression of analyte emission. The exact mechanism of this interference is unknown, and three-dimensional data will be provided to aid in characterizing the interference.

The Use of Pyridine to Quench the Dansylation of Amino Acids. KAY STEPHENS, SUZY POPE, ERIC R. JOHNSON AND TERRY L. KRUGER, Ball State University, Muncie, Indiana 47306.——In the derivatization of amino acids by dansylation, various amines have been used to quench the process by reaction with excess dansyl chloride (1-(N,N-dimethylamino)naphthalene-5-sulfonyl chloride). The most frequently used quenchers are small alkyl amines. While the resulting dansylated quencher peak can serve as a qualitative internal standard, its presence frequently complicates the separation and identification of the dansylated amino acids, especially when high sensitivity is desired. In this study, pyridine was found to efficiently quench the dansylation reaction without producing a dansylated quencher peak. With pyridine as the quencher, only dansic acid, which elutes well before the dansylated amino acids in the reverse phase HPLC separation, was increaed, which greatly simplified the development of the HPLC separation system for the dansylated amino acids.

Magnetic Resonance Investigation of Metal Complexes of Antidiabetic Drugs. KIMBERLY K. STROUSE AND ABBAS PEZESHK, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——In the course of our studies of metal binding properties of various antidiabetic drugs we have prepared copper and zinc complexes of tolbutamide and acetohexamide and studied their structures using ESR and NMR techniques. The spectroscopic data indicate that the metal ion is bound to deprotonated nitrogen atom of the drug to form 2:1 drug:metal complexes. The ESR spectra also indicates that both copper complexes have tetragonal symmetry ($g_{\parallel} > g_{\perp} > g_e$) with the unpaired electron in the $d_{x^2-y^2}$ orbital. The results of NMR, ESR, and X-ray analysis will be discussed and interpreted in terms of proposed structures.

Spectroscopic Studies of Spin-labeled Tetracycline Metal Complexes. STEPHEN C. SWINNEY AND ABBAS PEZESHK, Department of Chemistry, Ball State University, Muncie, Indiana 47306.——We report a new method for determining metal binding properties of tetracycline antibiotics using spin-labeling technique. The spin-labeled tetracycline (SLTC) was prepared and its interactions with metal ions were studied using electron spin resonance (ESR) and nuclear magnetic resonance (NMR) spectroscopy. We have investigated the interaction between SLTC and copper ions in aqueous and DMSO solutions at both room temperature and liquid nitrogen temperature using ESR spectroscopy. Analysis of the ESR data in DMSO solution indicates that the amide group is involved in metal complexation, and an exchange interaction was found between the unpaired electrons of hte copper ion and the nitroxyl radical. In aqueous solution, on the other hand, a weak exchange coupling was found between the unpaired electrons. The results on ESR and NMR studies will be presented.

Reactions of Phenyl (β-N-benzenesulfonyl indolyl) Iodonium Chloride with Soft Anions. ATILLA TUNCAY, Department of Chemistry, Indiana University Northwest, Gary, Indiana 46408 and ROBERT M. MORIARTY, Department of Chemistry, University of Illinois at Chicago, Chicago, Illinois 60607.——The reactions of phenyl (β-N-benzenesulfonyl indolyl) iodonium chloride with soft anions such as nitroethyl anion afforded N-benzenesulfonyl-3-iodoindole in excellent yields. The role of catalysts (copper salts), solvent and temperature was examined. The exclusive formation of the iodo compound is explained by a single electron transfer pathway. The present transformation will be discussed within the general context of nucleophilic displacement upon iodonium salts.

The Mechanism of L-Ascorbic Acid Entrapment in Human Erythrocytes. WILLIAM E. WHITE AND EUGENE S. WAGNER, Center for Medical Education, Ball State University, Muncie, Indiana 47306.——L-ascorbic acid-1-^{14}C when incubated with human blood migrates irreversibly into red blood cells. Isolation and characterization via IR of the moiety trapped within the cells established its identity as apparently unchanged L-ascorbic acid. When dehydroascorbic acid-1-^{14}C was incubated with human blood the results were identical including the identity of the entrapped moiety, L-ascorbic acid. Evidence will be presented to support the hypothesis that L-ascorbic acid is oxidized on the surface of the red blood cell to dehydroascorbic acid which migrates through the lipid portion of the cell membrane and is reduced back to L-ascorbic acid within the cell by glutathione reductase. The resulting L-ascorbic acid can not pass through the cell membrane and is therefore entrapped.

Michael Addition and Derivatives of 2-Carboxamido-3-phenylindenone[1]

E. Campaigne and David A. Templer
Department of Chemistry
Indiana University, Bloomington, Indiana 47405

Introduction

Recently we have submitted several reports (6,7,8) dealing with the synthesis and reactions of 3-substituted 2-carboxamidoindenones. Among the reactions which these compounds undergo is a fascile Michael addition, and we wish to report here the addition of a variety of nucleophiles to 2-carboxamido-3-phenylindenone (1) and some of the products derived from these compounds.

The Michael reaction, now one hundred years old, is a useful synthetic tool that has led to a vast amount of research on its scope and limitations. It is the subject of an extensive review (1). The reaction generally refers to the addition of a nucleophile to a conjugated double bond which involves a series of reversible equilibrium reactions. Thus the reverse of Michael addition may occur, and products may be unstable on isolation.

The synthesis of indenones *via* the cyclization of ylidenemalononitriles has been extensively studied in our laboratories (5). The first reported Michael addition to an indenone was rather recent. In 1960, Koelsch (9) found that 2-carbethoxy-3-phenyl-1-indenone reacts readily with a variety of carbanions and other nucleophiles to give Michael adducts, but he was unable to alkylate the intermediate ions formed by these reactions. Addition of hydroxide, alkoxide, or amines led to the isolation of unstable crude adducts, which reverted to the starting indenones on standing or in solution (10).

Discussion

The preparation of 3-cyano-3-phenyl-2-carboxamidoindanone (2a, Scheme 1) by the addition of cyanide to 1 has been previously reported (6). Contrary to observations of Koelsch (9), we were able to alkylate 2a readily by reaction with sodium hydride to form the anion, followed by addition of methyl iodide to produce 2-carboxamido-2-methyl-3-cyano-3-phenylindanone (3a) in good yield. Similarly, the 2-ethyl and 2-carbethoxymethyl derivatives 3b and 3c were formed by treating the anion of 2a with ethyl bromide or ethyl bromoacetate. In these cases, yields were improved by generating 3b or 3c from 1 in one step, by adding cyanide to 1 in dimethylsulfoxide, followed by reaction of the intermediate anion with alkylating agent.

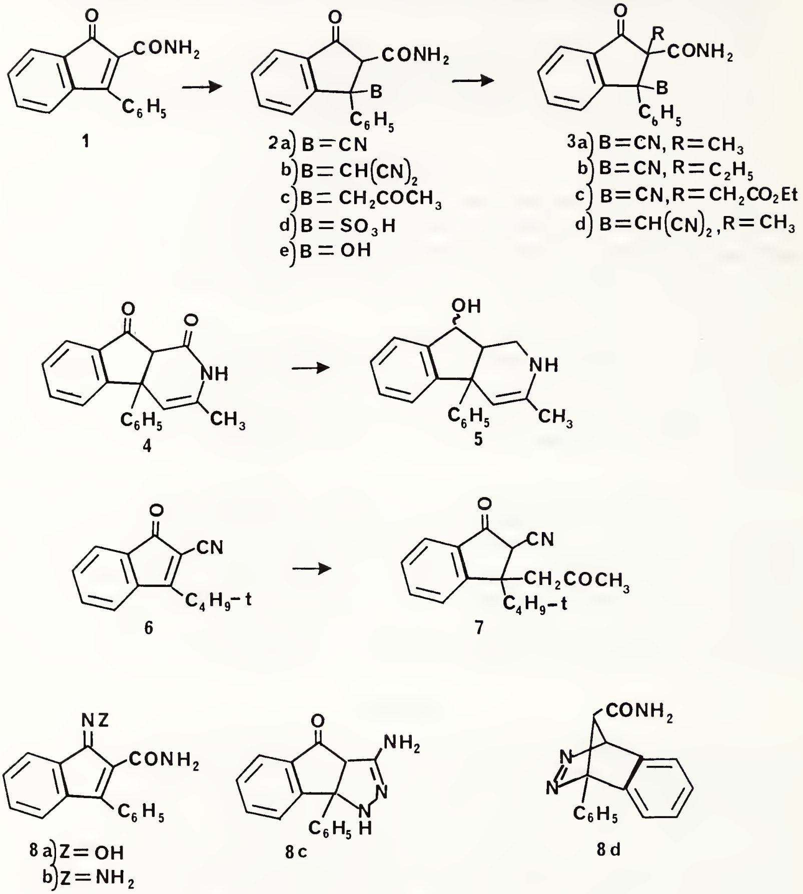
The anion of malononitrile adds readily to 1 as shown by the isolation of the methylated derivative 3d in 88% yield, after treatment of 1 with the sodium salt of malononitrile, followed by methyl iodide.

Sodium hydride reacts with acetone to generate a carbanion, which can behave as a Michael nucleophile. When a solution of 1 in acetone was treated with sodium hydride, a clear amber solution was obtained. When this solution was diluted with water and acidified, a new compound, 3-methyl-4a-phenyl-1,2,4a,9a-tetrahydro-2-azafluoren-1,9-dione (4), was obtained. This product must be the result of addition of acetonyl

---

[1] This work was supported in part by a grant from the Bristol Laboratories, Division of Bristol-Myers Co., Syracuse, NY, and is taken from a thesis submitted to Indiana University for the degree of Doctor of Philosophy by D.A. Templer, September, 1968.

SCHEME 1.



carbanion to 1, followed by a cyclodehydration reaction between the acetonyl ketone and the carboxamido group. That the cyclodehydration formed a carbon-carbon double bond rather than a carbon-nitrogen double bond was confirmed by the pmr spectrum which showed a vinyl proton multiplet and a methyl doublet. Reduction of 4 with lithium aluminum hydride produced the unsaturated amino-alcohol 5. Retention of the double bond in 5 confirms the structure of 4, since a carbon-nitrogen double bond should be reduced by lithium aluminum hydride.

In order to confirm the direct addition of acetone to an indenone, the reaction was attempted on 2-cyano-3-t-butyl-indenone (6). This compound, previously reported (4), could not be hydrated to 2-carboxamido-3-t-butyl-indenone, and hence should not undergo the secondary cyclodehydration step. Indeed, addition of sodium hydride to an acetone solution of 6 gave a high yield of the adduct 7.

Addition of non-carbon nucleophiles to indenone 1 met with varying degrees of success. Addition of the neutral nucleophile sodium bisulfite, followed by treatment with S-benzylisothiuronium chloride produced the S-benzylisothiuronium salt of the corresponding sulfonic acid 2d. The corresponding sodium salt of 2d was prepared by evaporating an alcohol solution of 1 which had been decolorized by addition of sodium bisulfite, but it could not be recrystallized, and acidification in solution led to the isolation of 1, formed by a reverse Michael addition of the acid 2d.

When orange indenone 1 was added to an ethanolic sodium hydroxide solution, after initial solution a white precipitate of the sodium salts of 2e formed, which dissolved on addition of water. Acidification gave a white solid which decomposed on the funnel to form indenone 1. This unstable white solid is undoubtedly the hydroxide adduct 2e. Attempts to trap the intermediate salt with methyl iodide failed and led to the isolation of 1 in 86% recovery.

Indenone 1 reacts with hydroxylamine or hydrazine to form simple 1:1 adducts which have lost a molecule of water, and are probably the simple oximes or hydrazones 8a and 8b. Since α, β-unsaturated ketones are known to react with hydroxylamine and hydrazine to form isoxazolines and pyrazolines *via* Michael additions, the possibility of such reactions occurring with indenone 1 had to be eliminated. Elementary analysis would not differentiate between the two possibilities. Infrared spectra are inconclusive, since unequivocal assignments cannot be made. However, the structure 8a for the hydroxylamine adduct is supported by the fact that the derivative is highly colored, indicating that the extended conjugated system is intact. Indeed, the ultraviolet spectrum of 1 and 8a are nearly identical. Finally any isoxazoline derived from 1 must have a bridgehead double bond, which is a violation of Bredt's rule (2).

The possibility of Michael addition of hydrazine followed by cyclization, with loss of water, to either the carboxamide group, to give the aminopyrazoline 8c or to the ketone with a hydride shift, to give pyrazoline 8d,are not so easily ruled out. Evidence for structures 8c or 8d are as follows: the compound is colorless, whereas compounds 1 and 8a, having the conjugated system, are yellow or orange. Compounds 1 and 8a have a strong ultraviolet absorption peak at 248 mμ, whereas the hydrazine adduct has a peak at 223 mμ, and none at 248 mμ. The compound decomposes with the evolution of gas at its melting point, a common property of pyrazoline derivatives like 8c or 8d. However, the pmr spectrum of the compound is consistent with the hydrazone structure 8b, showing only two peaks, roughly in a ratio of 11:2, a high field complex multiplet of aromatic and amide protons and a broad singlet at δ 4.17, indicating an NH_2 group. It is unlikely that the protons at N-1 and C-3a of 3-amino-4-oxo- 8b-phenyl-1,3a,4,8b-tetrahydro[1,2-c]pyrazole (8c), or those at C-1 and C-7 of 5,6-benzo-4-phenyl-7-carboximido-2,3-diazabicyclo[2.2.1]-2,5-heptadiene (8d), would have exactly the same chemical shift, or fall within the aromatic range. In addition, the lack of ketone absorption at about 5.85 μ in the infrared eliminates compound 8c. Therefore, we believe the hydrazone structure 8b is the most reasonable for this product.

Experimental

All melting points were determined in open capillary tubes with a Mel-Temp heating block apparatus and are corrected. The microanalyses were performed by Midwest Microlab, Inc., Indianapolis, IN, and Huffman Laboratories, Inc., Wheatridge, CO. Infrared spectra were determined in potassium bromide disks with a Perkin-Elmer Model 137 Infracord and were calibrated with polystyrene. Ultraviolet spectra were determined in 95% ethanol with a Bausch and Lomb Spectronic 505 Recording Spectrophotometer. Nuclear magnetic resonance spectra were obtained with a Varian A-60 spectrometer in the indicated solvents using tetramethylsilane as an internal standard.

2-Carboxamido-2-methyl-3-cyano-3-phenyl-1-indanone (3a).

Sodium hydride (0.26 g of 50% NaH in mineral oil, 5.5 mmoles) was added to a suspension of 2a , prepared as previously described (6), in tetrahydrofuran (20 mL); following the evolution of hydrogen methyl iodide (3 mL) was added. The reaction mixture was stirred at room temperature for 24 hr, diluted with 150 mL of water, and excess methyl iodide removed on a steam bath. The solution was cooled and the resulting precipitate collected by filtration to give 3a (0.95 g, 65%). Compound 3a was purified for analysis by recrystallization from 95% ethanol to give white crystals: mp 206-208°; ir 2.95 and 3.15 (NH_2), 4.44 (CN), 5.85 (CO), 5.98 ($CONH_2$), and 6.30 μ (aromatic); uv (λ max) 211 (ε 28,300), 250 (ε 13,700), and 295 mμ (ε 2,120); pmr (DMSO-d_6) δ 7.83 (4H multiplet, aromatic), 7.30 (7H, multiplet, aromatic and amide), and 1.80 (3H, singlet, methyl).

Anal. Calcd. for $C_{18}H_{14}N_2O_2$: C, 74.48; H, 4.82; N, 9.65. Found: C, 74.27; H, 4.95; N, 9.65.

2-Carboxamido-2-ethyl-3-cyano-3-phenyl-1-indanone (3b).

A mixture of indenone 1 (3) (5 g, 20 mmoles) and 1.5 g of sodium cyanide (30.8 mmoles) in 35 mL of dimethylsulfoxide was warmed on a steam bath to give a red solution. The solution was cooled and excess (5 mL) of ethyl bromide added. After 48 hr the reaction mixture was diluted with water and excess ethyl bromide removed on a steam bath. The solution was cooled and a white precipitate was collected and recrystallized from ethanol to give 5.7 g (94%) of white crystals of 3b melting at 208-210°; ir 2.84, 2.94 (NH_2), 4.43 (CN), 5.97 (CO) and 6.05μ ($CONH_2$).

Anal. Calcd. for $C_{19}H_{16}N_2O_2$: C, 75.00; H, 5.26; N, 9.21. Found: C, 75.08; H, 5.51; N, 9.26.

2-Carboxamido-2-carbethoxymethyl-3-cyano-3-phenyl-1-indanone (3c).

Following the procedure described above for 3b, 5 g (20 mmoles) of 1 was treated with an excess (5 g) of ethyl bromoacetate. The product, which melted at 168-169° after two recrystallizations from isopropanol, weighed 7.0 g (93%); ir 2.90 (NH), 4.45 (CN), 5.72 (COOR), 5.92 (CO) and 6.02 μ ($CONH_2$).

Anal. Calcd. for $C_{21}H_{18}N_2O_4$: C, 69.61; H, 4.97; N, 7.73. Found: C, 69.35; H, 5.01; N, 7.77.

2-Carboxamido-2-methyl-3-dicyanomethyl-3-phenyl-1-indanone (3d).

The sodium salt of malononitrile was prepared by the addition of sodium hydride (0.75 g of 50% NaH in mineral oil, 15.6 mmoles) to a solution of malononitrile (1.3 g, 20 mmoles) in dimethyl sulfoxide (25 mL). The solution was stirred at room temperature for 15 min and then 2-carboxamido-3-phenyl-1-indenone (1) (2.49 g, 10 mmoles) was added to the reaction mixture. The solution was stirred at room temperature for 1.5 hr, methyl iodide (5 mL) was added and the solution stirred for an additional 48 hr. The reaction was quenched with 300 mL of water and the excess methyl iodide was removed on a steam bath. The resulting solid was collected by filtration to give 2.9 g (88%) of 3d, mp 218-222°. Recrystallization from 95% ethanol (Norit) gave an analytical sample of white plates, mp 239-240° (dec) with partial melting at 200°; a sample of this compound maintained at 200° completely melted after 1.5 hr; ir 2.90 and 3.00 (NH_2), 3.37 and 3.40 (CH), 4.43 (CN), 5.82 (CO), 6.00 ($CONH_2$) and 6.31μ (phenyl); pmr (DMSO-d_6) δ 7.9-7.3 (11H, complex multiplet, aromatic and amide), 6.80 (1H, singlet, methine), and 0.90 (3H, singlet, methyl).

Anal. Calcd. for $C_{20}H_{15}N_3O_2$: C, 72.95; H, 4.56; N, 12.76. Found: C, 73.09; H, 4.77; N, 12.78.

3-Methyl-4a-phenyl-1,2,4a,9a-tetrahydro-2-azafluoren-1,9-dione (4).

To a solution of compound 1 (3.0 g, 12.1 mmoles) in acetone (100 mL) was added sodium hydride (0.7 g of 53.7% NaH in mineral oil, 15.7 mmoles). The solution was stirred at room temperature for 30 min, diluted with water (300 mL) and acidified with 20% sulfuric acid. The excess acetone was removed under a stream of air and the resulting precipitate was collected by filtration to give 3.15 g (90%) of 4, mp 214-216°.

Recrystallization from 95% ethanol gave white crystals: mp 230-231°; ir 3.15 (NH), 5.77 (CO) and 6.00 μ (CONH); pmr (DMSO-d_6) δ 7.85-7.20 (9H, multiplet, aromatic), 6.30 (1H, multiplet, vinyl), 4.90 (1H, doublet, J = 1 cps, due to long range coupling, methine), 1.77 (3H, doublet, J = 2 cps, methyl).

Anal. Calcd. for $C_{19}H_{15}NO_2$: C, 79.04; H, 5.19; N, 4.84. Found: C, 79.21; H, 5.22; N, 4.83.

3-Methyl-4a-phenyl-1,2,4a,9a-tetrahydro-2-azafluoren-9-ol (5).

A solution of compound 4 (12 g, 41.5 mmoles) in tetrahydrofuran (500 mL) was added dropwise to a refluxing mixture of lithium aluminum hydride (18 g, 95%, 0.5 mol) in tetrahydrofuran (125 mL), and the mixture was refluxed for 5 hr with stirring. The reaction mixture was cooled and the excess hydride was cautiously hydrolyzed with saturated sodium sulfate solution. The resulting solid was removed by filtration and rinsed with chloroform. The chloroform-tetrahydrofuran solution was dried (magnesium sulfate), decolorized (activated charcoal) and concentrated to dryness at reduced pressure. The resulting oil was triturated with petroleum ether to produce 8 g (69%) of 5. Three recrystallizations from acetonitrile gave light beige plates: mp 179-181°; ir 3.0-3.15 (OH-NH hydrogen bonded), 6.00 (C=C), and 6.24μ (aromatic).

Anal. Calcd. for $C_{19}H_{19}NO$: C, 82.31; H, 6.86; N, 5.05. Found: C, 82.31; H, 6.79; N, 5.06.

2-Cyano-3-acetonyl-3-t-gutyl-1-indanone (7).

Sodium hydride (1.45 g of 53.7% NaH in mineral oil, 32.6 mmoles) was cautiously added to a solution of compound 6 (3) (6.0 g, 28.4 mmoles) in acetone (180 mL). The mixture was stirred at room temperature for 40 min. The resulting clear amber solution was diluted with water (300 mL) and acidified to pH 4 with 20% sulfuric acid. The excess acetone was removed under a stream of air. The solid was collected by filtration, yielding 7.4 g (97%) of 7, melting at 172-172.5°. Several recrystallizations from isopropanol yielded white crystals: mp 176-178°; ir 4.48 (CN), 5.8.5.9μ (CO); pmr ($CDCl_3$) δ 7.92-7.32 (4H, multiplet, aromatic), 3.80 (1H, singlet, methine), 3.32 (2H, singlet, methylene), 2.03 (3H, singlet, methyl), and 1.08 (9H, singlet, t-butyl).

Anal. Calcd. for $C_{17}H_{19}NO_2$: C, 75.98; H, 7.07. Found: C, 76.14; H, 7.26.

Salts of 2-Carboxamido-3-phenyl-1-indanone-3-sulfonic Acid (2d).

A mixture of indenone 1 (2.49 g, 10 mmoles), sodium bisulfite (1.1 g, 10.5 mmoles) and 50% ethanol (50 ml) was heated on a steam bath until a clear amber solution was obtained (10 min). The solution was then evaporated to dryness at reduced pressure to give 3.5 g (99%) of the sodium salt of 2d. The S-benzyl-isothiouronium salt was prepared by dissolving this salt (1 g, 2.84 mmoles) in 10 mL of water and adding S-benzylisothiouronium chloride (1.01) g, 5 mmoles) in 5 mL of water. The precipitate was collected by filtration, yielding 1.35 g (96%) of S-benzylisothiouronium 2-carbamyl-3-phenyl-1-indanone-3-sulfonate. An analytical sample was prepared by recrystallization from 50% ethanol (care must be taken in recrystallization, because a retro-Michael reaction occurs on prolonged heating as evidenced by the formation of an orange color.): mp 148-151° (dec), ir 2.9-3.3 (H-bonding), 5.80 (CO, weak), 6.0-6.15 and 6.20-6.40 ($CONH_2$ and enol and aromatic carbon-carbon double bonds), and 6.98 and 8.3-8.6μ (SO_3).

Anal. Calcd. for $C_{24}H_{23}N_3O_5S_2$: C, 57.94; H, 4.66; N, 8.45. Found: C, 58.06; H, 4.83; N, 8.54.

Attempted Addion of Hydroxide to Indenone 1.

A mixture of orange indenone 1 (1.2 g, 4.7 mmoles), 10% sodium hydroxide (10 mL) and 95% ethanol was stirred at room temperature; after 3 hr a voluminous white precipitate formed. The precipitate dissolved upon addition of 200 mL of water, acidification produced a white precipitate, which turned orange on standing to give 1.15 g (96%) of starting indenone 1 as evidenced by congruent infrared spectrum and melting point.

A mixture of indenone 1, 10% sodium hydroxide (15 mL), and 95% ethanol (25 mL) was stirred at room temperature; after 3 hr the orange color disappeared and a voluminous white precipitate formed. The mixture was treated with methyl iodide (6 mL), stirred at room temperature for 24 hr, then quenched with 250 mL of water and the excess methyl iodide removed on a steam bath. The cooled solution afforded 1.85 g (74%) of starting material and acidification of the solution yielded an additional 0.3 g (12%) of indenone 1 as shown by infrared spectrum, color, and melting point.

2-Carboxamido-3-phenylinden-1-oxime (8a).

A solution of indenone 1 (2.49 g, 10 mmoles), hydroxylamine hydrochloride (0.69 g, 10 mmoles) and pyridine (0.79 g, 10 mmoles) in 100 mL of 95% ethanol was refluxed with stirring for 3 hr. The reaction was poured into 200 mL of water and the resulting solid (2.35 g, 89%) collected by filtration. Recrystallization from 95% ethanol afforded an analytical sample of golden prisms: mp 238.5-240° (dec); ir 3.00-3.40 (broad H-bonding), 6.00 ($CONH_2$), and 6.30 and 6.44μ (C = C and C = N); uv (λ max) 248 (ε 38,000), 270 (broad shoulder, ε 21,000), and 305-325mμ (ε 10,500).

Anal. Calcd. for $C_{16}H_{12}N_2O_2$: C, 72.72; H, 4.54; N, 10.61. Found: C, 72.74; H, 4.79; N, 10.53.

2-Carboxamido-3-phenylinden-1-hydrazone (8b).

Indenone 1 (5.0 g, 20 mmoles) was dissolved in 400mL of 95% ethanol by warming on a steam bath, and hydrazine hydrate (85%, 1.16 g, 20 mmoles) was added to the solution. The reaction was kept at room temperature for 3 hr and the clear solution concentrated to a volume of 100 mL on a hot plate, cooled in an ice bath and the resulting white solid collected to give 4.35 g (82%) of 8b, mp 216-218°. Recrystallization from 95% ethanol afforded an analytical sample of white crystals: mp 218.5-220° with decomposition and gas evolution; ir 2.98 and 3.15 (NH), 6.00 ($CONH_2$), and 6.18 and 6.40μ (C = C and C = N); uv (λ max) 223 (ε 36,200) and 280 mμ (ε 9,800); pmr (DMSO-d_6) the spectrum showed only two peaks in a ratio of 11 H to 1.8 H which were at δ 8.3-7.17 (complex aromatic and amide multiplet) and 4.17 (singlet NH_2), respectively.

Anal. Calcd. for $C_{16}H_{13}N_3O$: C, 73.00; H, 4.94; N, 15.96. Found: C, 72.97; H, 5.14; N, 15.94.

Literature Cited

1. Bergmann, E.D., D. Ginsberg and R. Pappo, 1959. The Michael Reaction. Org. Reactions *10*: 179-555.
2. Bredt, J., 1924. Uber sterische Hinderung in Brückenringen (Bredtsche Regel) und über die meso-trans Stellung in Kondensierten Ringsystem des Hexamethylens. Lieb. Ann. *437*: 1-13.
3. Campaigne, E., G.F. Bulbenko, W.E. Krieghbaum, and D.R. Maulding, 1962. Ring Closure of Ylidenemalononitriles. J. Org. Chem. *27*: 4428-4432.
4. Campaigne, E. and D.R. Maulding, 1963. Rearrangement of 2-Cyano-3-t-butyl-1-indenone. J. Org. Chem. *28*: 1391-1393.
5. Campaigne, E. and S.W. Schneller, 1976. Cyclization of Ylidenemalonodinitriles. Synthesis, No. *11*: 705-716.
6. Campaigne, E. and R.F. Weddleton, 1986. Succinimido[3,4-b]indan-8-one Derivatives. Proc. Ind. Acad. Sci. *95*: 167-170.
7. Campaigne, E. and R.F. Weddleton, 1986. Substituted Derivatives of 3a,4,5,6-tetrahydrosuccinimido[3,4-b]acenaphthen-10-one. Proc. Ind. Acad. Sci. *95*: 159-165.

8. Campaigne, E. and E.M. Yokley, 1980. Tetrahydropyrrolidoacenaphthene and Benzazapropellane Derivatives as Potential Analgetics and Narcotic Antagonists. Proc. Ind. Acad. Sci. *89*: 136-141.
9. Koelsch, C.F., 1960. Electrophilic Properties of Ethyl 3-Phenylindone-2-carboxylate. J. Org. Chem. *25*: 2088-2094.
10. Koelsch, C.F., 1961. An Indone to Naphthol Ring Expansion. J. Org. Chem. *26*: 1003-1005.

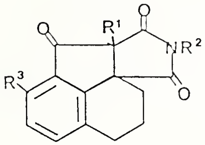
Substituted Derivatives of 3a,4,5,6-Tetrahydrosuccinimido[3,4-b]acenaphthen-10-one.II.[1]

E. CAMPAIGNE AND DAVID A. TEMPLER
Department of Chemistry
Indiana University, Bloomington, Indiana 47405

Introduction

The preparation and biological activity of a number of derivatives of 3a,4,5,6-tetrahydrosuccinimido[3,4-b]acenaphthen-10-one (1a) have recently been reported (2). Compound 1a served as a lead compound, since it had interesting biological activity (1). It was therefore interesting to prepare various derivatives for further biological screening. In the first report (2) we described compounds of structure 1, where substitution on nitrogen, R^2, included a variety of pharmacophoric groups, and substitution on the aromatic ring at R^3 included methyl and methoxy groups. We wish to report here compounds of structure 1, where R^3 is H, R^2 is H or CH_3, and R^1 may be methyl, ethyl or allyl.

FIGURE 1.



1

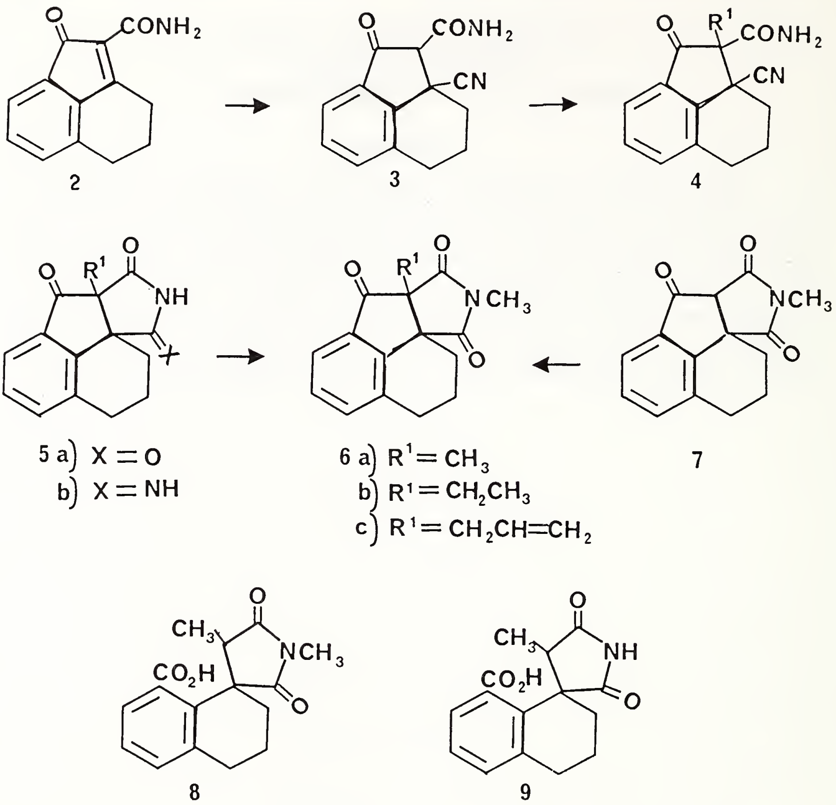
a. $R^1 = H$, $R^2 = H$, $R^3 = H$
b. $R^1 = CH_3$, $R^2 = H$, $R^3 = H$
c. $R^1 = C_2H_5$, $R^2 = H$, $R^3 = H$
d. $R^1 = H$, $R^2 = CH_3$, $R^3 = H$
e. $R^1 = CH_3$, $R^2 = CH_3$, $R^3 = H$
f. $R^1 = C_2H_5$, $R^2 = CH_3$, $R^3 = H$
g. $R^1 = C_3H_6$, $R^2 = CH_3$, $R^3 = H$

We have shown that cyanide ion adds smoothly *via* a Michael reaction to indenone 2 to form the cyanide adduct 3 in high yield (1,2) (Scheme 1). The obvious approach to the synthesis of compounds 1, with substituents at the 10a position (e.g., 1b or 1c) would involve alkylation of the anion derived from 3, which has an acidic α-hydrogen. Indeed, this anion is an intermediate in the Michael addition, and could be alkylated directly, to provide a one-step conversion of 2 to 4 (Scheme 1). However, Koelsch (6) has reported that all attempts to alkylate the cyanide adduct of ethyl 3-phenyl-1-indenone-2-carboxylate were unsuccessful. However, alkylation of intermediate anions derived from Michael addition of cyanide to acyclic unsaturated compounds have been reported (4,7). Koelsch (6) attributed failure of alkylation to the fact that the intermediate anion is a weak base, in which the anion site is flanked by bulky groups. He noted that mono-tertiary alkylated malonic and acetoacetic esters are resistant to alkylation.

---

[1] Taken in part from a thesis submitted to Indiana University by D.A.T. in partial fulfillment of the requirements for the degree of Doctor of Philosophy, September, 1968. This work was supported in part by a grant from Bristol Laboratories, Syracuse, NY.

SCHEME 1.



Discussion

We have found that the anion of 3, formed by addition of cyanide to 2, may be alkylated in good yield in several polar solvents. Thus a mixture of 2 and sodium cyanide in DMSO (dimethylsulfoxide), DMF (dimethylformamide) or *t*-butyl alcohol/water mixture, treated with methyl iodide produced 4a ($R^1 = CH_3$) in yields ranging from 53% to 85%. However, attempts to methylate the anion of 3 with dimethyl sulfate in DMSO or DMF were unsuccessful.

On melting at 214-217°, compound 4a was found to resolidify and melt again at 251-254°. This product was shown to be isomeric with 4a, and was assigned the iminopyrrolidine structure 5b ($R^1 = CH_3$) on the basis of its spectral characteristics and ready hydroylsis to 5a ($R^1 = CH_3$). The propensity for cyclization of 4a to 5b on heating, coupled with the pmr spectrum of 4a which showed only one methyl singlet, indicate that the addition of cyanide and alkylation proceed in a nearly exclusive *trans* manner to give an adduct in which cyanide and carbamoyl functions are *cis*-oriented. It should be noted that this ready cyclization exhibited by 4a on heating was not observed with other Michael adducts.

The desired 10a-alkylated derivatives of 1 were prepared by the acid-catalyzed cyclization of compounds 4 (1). Since compound 1a has an active hydrogen at the 10a position, it should also be possible to alkylate the parent 1a. However, it would be necessary to block the acidic imide hydrogen, which is readily methylated (3) to produce compound 7. Treatment of 7 with sodium hydride and an alkylating agent gave the 10a-alkylated 2-methyl derivatives 6. Compounds 5a could also be methylated on nitrogen to produce 6.

An attempt was made to prepare 6a directly by dimethylation of compound 1a, using a three-fold excess of sodium hydride, followed by excess methyl iodide. When the reaction mixture was hydrolyzed, the dimethyl derivative 6a did not precipitate, but acidification of the hydrolysate led to the isolation of a crystalline acid, 8, as evidenced by elemental analysis and spectral properties. This same acid was produced when 6a was treated with sodium hydroxide in aqueous tetrahydrofuran, the result of characteristic acid cleavage of β-ketoacid derivatives (5). The isolation of 8 from 1a indicates that dimethylation had occurred before acid cleavage by excess base present. Solution of 5a ($R^1 = CH_3$) in aqueous potassium hydroxide, followed by acidification, produced the spiro acid derivative 9. This fascile acid cleavage of these fused-ring β-ketoamides may be facilitated by relief of strain in these systems, as well as the known ease of cleavage of α, α-disubstituted β-ketoacid derivatives (5).

Pharmacological Results

Compounds 4a-g, 5a ($R^1 = CH_3$ and $R^1 = C_2H_5$), 6a-c, 7 and 8 were submitted to Bristol Laboratories, Division of Bristol-Myers Co., Syracuse, NY, for pharmacological evaluation.[2]

Although none of the compounds exhibited anticonvulsant activity, other activities were observed. Compounds 4c (R = allyl), 5a ($R^1 = C_2H_5$), 6a and 8 were found to inhibit gastric secretion in rats when administered intraperitoneally, and compound 6b demonstrated smooth muscle relaxant activity *in vitro*.

The modifications of structure 1 described here and earlier (2), in which different substituents have been placed at R^1, R^2 and R^3 have all led to compounds inactive as anticonvulsants. Lack of activity of these derivatives indicates that a high degree of specificity is inherent in the activity of 1a. Lack of activity in the N-alkylated derivatives clearly indicates need for a free imide hydrogen. However, the lack of activity in derivatives of 5a is surprising, since the imide ring projects approximately 70° out of the plane of the nearly planar acenaphthenone ring system and the newly introduced alkyl groups are projecting in the opposite direction.

Experimental

All melting points were determined in open capillary tubes with a Mel-Temp heating block and are corrected. Microanalyses were performed by Midwest Microlab, Inc., Indianapolis, IN. Infrared spectra were determined in potassium bromide disks with a Perkin-Elmer Model 137 Infracord, and were calibrated with polystyrene. Ultraviolet spectra were determined in 95% ethanol with a Bausch and Lomb Spectronic 505 Recording Spectrophotometer. Nuclear magnetic resonance spectra were obtained with a Varian A-60 spectrometer in indicated solvents using tetramethylsilane as an internal standard, except when hexadeuteriodimethyl-sulfoxide was the solvent, sodium 2,2-dimethyl-2-silapentane 5-sulfonate (DDS) was used as the standard.

2-Carbamoyl-2-methyl-2a-cyano-2a,3,4,5-tetrahydroacenaphthen-1-one (4a, $R^1 = CH_3$).

A mixture of indenone 2 (5 g, 23.5 mmoles) prepared as previously reported (1), and sodium cyanide (1.5 g, 30.8 mmoles) in DMSO (35 mL) was warmed on a steam bath to give a deep red solution. The solution was cooled and treated with methyl iodide (10 g). After 48 hr the reaction mixture was diluted with 250 mL of water and the excess methyl iodide was removed on a steam bath. The solution was cooled and the resulting precipitate was collected by filtration to give 4a (5.05 g, 85%). An analytical sample of 4a (white plates) was obtained by recrystallization from 95% ethanol: mp 214-217°, solidified and remelted 251-254°; ir 2.95 and 3.19 (NH_2), 3.39 (CH), 4.47 (CN), 5.83 (CO), 5.94 ($CONH_2$), and 6.29 μ (aromatic); uv (λ max) 211 (ϵ 22,800), 261 (ϵ 13,500), and 300 mμ (ϵ 3,160); pmr (DMSO-d_6) δ 7.66 (5H, multiplet, aromatic and amide), 3.15-2.05 (methylene multiplet obscured by DMSO), and 1.30 (3H, singlet, methyl).

---

[2] We are indebted to Dr. M.H. Pindell of Bristol Laboratories for supplying selected preliminary test data.

Anal. Calcd. for $C_{15}H_{14}N_2O_2$: C, 70.87; H, 5.51; N, 11.02. Found: C, 70.77; H, 5.77; N, 11.25.

Compound 4a was also prepared in 66% yield in DMF following the procedure described above.

A mixture of indenone 2 (4.8 g, 22.5 mmoles) and sodium cyanide (1.5 g, 30.8 mmoles) in a solution of t-butanol (50 mL) and water (50 mL) was warmed on a steam bath to effect solution (yellow). The solution was cooled, treated with methyl iodide (20 g), the two phase system stirred for 72 hr and the resulting precipitate collected to give 4a (3.0 g, 53%).

3-Imino-10a-methyl-1-oxo-3a,4,5,6-tetrahydropyrrolidino[3,4-b]acenaphthen-10-one (5b, $R^1 = CH_3$).

A flask containing 4a (1.5 g, 5.9 mmoles) was heated in an oil bath to 235° (the compound melted). The flask was cooled and the resulting solid recrystallized from 95% ethanol to yield 5b (0.9 g, 60%) as white plates; mp 258-261°; ir 2.81 and 2.95 (NH), 3.35 (CH), 5.76 (imide carbonyl), 5.85 (ketone carbonyl), 6.00 (C=N), and 6.27 μ (aromatic).

Anal. Calcd. for $C_{15}H_{14}N_2O_2$: C, 70.86; H, 5.51; N, 11.02. Found: C, 70.85; H, 5.75; N, 10.64.

2-Carbamoyl-2-ethyl-2a-cyano-2a,3,4,5-tetrahydroacenaphthen-1-one (4b, $R^1 = C_2H_5$).

Following the procedure described above for 4a in DMSO, the cyanide adduct of 5 g (23.5 mmoles) of 2 was treated with excess ethyl bromide, to give 3.65 g (58%) of 4b, white crystals melting at 214-215° after recrystallization from ethanol; ir 2.92 (NH_2), 4.45 (CN), 5.84 (CO) and 5.94 μ ($CONH_2$).

Anal. Calcd. for $C_{16}H_{16}N_2O_2$: C, 71.66; H, 6.38; N, 10.44. Found: C, 71.90; H, 6.11; N, 10.35.

2-Carbamoyl-2-allyl-2a-cyano-2a,3,4,5-tetrahydroacenaphthen-1-one (4c, $R^1 = CH_2CH{=}CH_2$).

As above, treatment of the solution with allyl bromide gave 4c in 81% yield, melting at 200-201°; ir 2.92 (NH_2), 4.44 (CN), 5.84 (CO). 5.90 ($CONH_2$), 10.03 and 10.95 μ (allyl C=C).

Anal. Calcd. for $C_{17}H_{16}N_2O_2$: C, 72.83; H, 5.75; N, 10.00. Found: C, 72.49; H, 5.78; N, 10.00.

2-Carbamoyl-2-carbethoxymethyl-2a-cyano-2a,3,4,5-tetrahydroacenaphthen-1-one (4d, $R^1 = CH_2COOC_2H_5$).

Following the above procedure, 5 g (23.5 mmoles) of 2 was treated with cyanide followed by 4.1 g (24.5 mmoles) of ethyl bromoacetate. The product, worked up in the usual manner and recrystallized from ethanol, gave 4.82 g (63%) of white crystals of 4d, melting at 205-207°; ir 2.91 (NH_2), 4.48 (CN), 5.74 (COOR), 5.84 (CO) and 5.93 μ ($CONH_2$).

Anal. Calcd. for $C_{18}H_{18}N_2O_4$: C, 66.24; H, 5.56; N, 8.59. Found: C, 66.39; H, 5.65; N, 8.43.

2-Carbamoyl-2-butyl-2a-cyano-2a,3,4,5-tetrahydroacenaphthen-1-one (4e, R' = C_4H_9-n).

Following the procedure for the preparation of4a, and using excess 1-bromobutane (Aldrich), compound 4e was obtained in 91% yield as white crystals melting at 138-140° after recrystallization from benzene: ir 2.95 (NH_2), 4.47 (CN), 5.85 (CO) and 5.95 μ ($CONH_2$).

Anal. Calcd. for $C_{18}H_{20}N_2O_2$: C, 72.95; H, 6.80; N, 9.46. Found: C, 73.11; H, 7.06; N, 9.72.

2-Carbamoyl-2-hexyl-2a-cyano-2a,3,4,5-tetrahydroacenaphthen-1-one (4f, R' = C_6H_{13}-n).

Following the procedure described for 4d, 3.96 g (24 mmoles) of 1-bromohexane (Aldrich) was added to the mixture, to give on work-up 6.24 g (82%) of 4f, melting at 158-159° after recrystallization from benzene: ir 2.88 (NH_2), 4.47 (CN), 5.79 (CO) and 6.09 μ ($CONH_2$?).

Anal. Calcd. for $C_{20}H_{24}N_2O_2$: C, 74.04; H, 7.46; N, 8.64. Found, C, 73.91; H, 7.62; N, 8.83.

2-Carbamoyl-2-benzyl-2a-cyano-2a,3,4,5-tetrahydroacenaphthen-1-one (4g, R' = $CH_2C_6H_5$).

Following the procedure for 4d, 3.0 g (23.7 mmoles) of benzyl chloride was added, and the usual work-up gave 7.60 g (98%) of white crystals melting at 238-240° after recrystallization from ethanol; ir 2.92 (NH_2), 4.48 (CN), 5.85 (CO) and 5.96 μ ($CONH_2$).

Anal. Calcd. for $C_{21}H_{18}N_2O_2$: C, 76.34; H, 5.49; N, 8.48. Found: C, 76.21; H, 5.65; N, 8.70. .

10a-Methyl-3a,4,5,6-tetrahydrosuccinimido[3,4-b]acenaphthen-10-one (5a, R' = CH_3).

Polyphosphoric acid (100 g) was added to a flask containing 4a (3.6 g, 14.2 mmoles). The mixture was stirred w ith a mechanical stirrer at 105° for 7 hr, and then hydrolyzed by pouring onto 750 mL of cracked ice. After 24 hr, the resulting solid was collected by filtration to give 5a (2.3 g, 63%), mp 238-241°. Recrystallization from 95% ethanol afforded an analytical sample of white crystals: mp 249-251°; ir 3.12 (NH), 3.38 (CH), 5.60 and 5.89 (imide carbonyls), 5.78 (ketone carbonyl), and 6.29 μ (aromatic).

Anal. Calcd. for $C_{15}H_{13}NO_3$: C, 70.59; H, 5.10; N, 5.49. Found: C, 70.66; H, 5.24; N, 5.42.

10a-Ethyl-3a,4,5,6-tetrahydrosuccinimido[3,4-b]acenaphthen-10-one (5a, R' = C_2H_5).

Following the procedure described above, 5a, R' = C_2H_5 was prepared in 79.2% yield from 4b. An analytical sample was prepared by recrystallization from 95% ethanol: mp 247-248°; ir 3.14 (NH), 5.64 and 5.92 (imide carbonyls), and 5.80 μ (ketone carbonyl).

Anal. Calcd. for $C_{16}H_{15}NO_3$: C, 71.36; H, 5.61; N, 5.20. Found: C, 71.10; H, 5.59; N, 5.46.

2-Methyl-3a,4,5,6-tetrahydrosuccinimido[3,4-b]acenaphthen-10-one (7).

This compound was prepared as previously reported (3), by methylation of 2.4 g (0.1 mole) of 1a (1) with methyl iodide in DMF. The resulting solid recrystallized from ethanol to give 2.5 (88%) of 7 as white crystals melting at 142.5-144°*; ir 3.38 (CH), 5.61* and 5.92 (imide (CO), 5.80 (CO) and 6.29 μ (aromatic).

Anal. Calcd. for $C_{15}H_{13}NO_3$: C, 70.54; H, 5.09; N, 5.49. Found: C, 70.25; H, 5.34; N, 5.47.

2,10a-Dimethyl-3a,4,5,6-tetrahydrosuccinimido[3,4-b]acenaphthen-10-one (6a, R' = CH_3).

Sodium hydride (0.55 g of 50% NaH in mineral oil, 11.4 mmoles) was added to a mixtûre of 7 (2.55 g, 10 mmoles) in 30 mL of dry THF in an Erlenmeyer flask fitted with a drying tube (Drierite). After the evolution of hydrogen, methyl iodide (5 mL) was added and the mixture stirred at room temperature for 24 hr, then poured into 250 mL of water and the excess methyl iodide removed on a steam bath. The resulting solid was collected by filtration to give 6a (2.22 g, 83%, mp 137-138°). When the reaction was run in DMSO, 6a was isolated in 74% yield. An analytical sampe of 6a was prepared by recrystallization from 95% ethanol as white crystals: mp 143-144°; ir 3.40 (CH), 5.61 and 5.90 (imide carbonyl), 5.79 (ketone carbonyl), and 6.29 μ (aromatic); pmr ($CDCl_3$) δ 7.52 (3H, multiplet, aromatic), 2.95 (3H, singlet, NCH_3), 2.6-1.7 (multiplet, methylene), and 1.47 (3H, singlet, CH_3).

Anal. Calcd. for $C_{16}H_{15}NO_3$: C, 71.37; H, 5.57; N, 5.20. Found: C, 71.66; H, 5.85; N, 5.06.

A mixture of 5a ($R^1 = CH_3$) (0.47 g, 1.84 mmoles), potassium carbonate (0.27 g, 1.95 mmoles) and methyl iodide (2mL) in 6mL of DMF was stirred at room temperature for 20 hr. The reaction was poured into 100 mL of water and the resulting solid was collected to give 0.41 g (83%) of white crystals melting at 138.5-140°. A sample was recrystallized from 50% ethanol, and melted at 143-144°. This compound was identical to 6a prepared by methylation of 7 as evidenced by identical infrared spectrum and undepressed mixture melting point.

10a-Ethyl-2-methyl-3a,4,5,6-tetrahydrosuccinimido[3,4-b]acenaphthen-10-one (6b, $R^1 = C_2H_5$).

Following the procedure outlined for the preparation of 6a, 6b was obtained in 72% yield from 7 and ethyl iodide. An analytical sample was prepared by recrystallization from aqueous ethanol: mp 103.5-104.5°; ir 3.41 (CH), 5.63 and 5.91 (imide carbonyls), 5.80 (ketone carbonyl) and 6.29 μ (aromatic).

Anal. Calcd. for $C_{17}H_{17}NO_3$: C, 72.08; H, 6.00; N, 4.94. Found: C, 71.99; H, 6.12; N, 4.90.

10a-Allyl-2-methyl-3a,4,5,6-succinimido[3,4-b]acenaphthen-10-one (6c, $R^1 = C_3H_6$).

Following the procedure outlined for the preparation 6a, 6c was obtained in 46% yield from 7 and allyl bromide. An analytical sample was prepared by recrystallization from 95% ethanol: mp 83-84°; ir 3.4 (CH), 5.62 and 5.92 (imide carbonyls), 5.80 (ketone carbonyl), 6.1 (C=C), 6.29 (aromatic), and 10.05 and 10.78 μ (allyl).

Anal. Calcd. for $C_{18}H_{17}NO_3$: C, 73.22; H, 5.76; N, 4.75. Found: C, 72.94; H, 5.72; N, 4.73.

Spiro[8′-carboxy-1′,2′,3′,4′-tetrahydronaphthene-1′,3-1,4-dimethylsuccinimide] (8).

Sodium hydride (1.5 g of 50% NaH in mineral oil, 31.2 mmoles) was added to a mixture of 1a (1) (2.41 g, 10 mmoles) in 75 mL of dry THF in an Erlenmeyer flask fitted with a drying tube (Drierite). After the evolution of hydrogen, excess methyl iodide (10 mL) was added, the solution was stirred at room temperature for 24 hr, poured into 300 mL of water and the excess methyl iodide was removed on a steam bath. After cooling in an ice-water slurry, the solution was acidified with 20% sulfuric acid to pH 1. The resulting precipitate was collected to give 2.88 g (100%) of 8 melting at 210-212°. Compound 8 was purified for analysis by recrystallization from benzene: mp 215-218°; ir 3.0-3.2 and 3.7-3.9 (H-bonding), 3.36 (CH), 5.61 and 5.90 (imide carbonyls), 5.78 (acid carbonyl), and 6.28μ (aromatic); pmr ($CDCl_3$) δ 8.95 (1H, singlet, acid), 7.77 (1H, multiplet, aromatic), 7.29 (2H, multiplet, aromatic), 3.10 (3H, singlet, NCH_3), 2.85 (3H, multiplet, methylene), 2.00 (4H, multiplet, methylene), and 1.04 (3H, doublet, J = 8 cps, CCH_3); the compound is soluble in sodium bicarbonate solution.

Anal. Calcd. for $C_{16}H_{17}NO_4$: C, 66.89; H, 5.92; N, 4.88. Found: C, 66.68; H, 5.98; N, 4.77.

The dimethylated imide 6a (1.3 g, 5 mmoles) was added to a solution of 2.1 mL of

10% sodium hydroxide (5.1 mmoles) in 10 mL of water and 10 mL of THF, and the mixture was stirred at room temperature for 4 hr to produce a clear solution. The solution was acidified to pH 1 with 20% sulfuric acid and extracted with chloroform. The chloroform phase was dried with magnesium sulfate and concentrated to dryness at reduced pressure to give 8 (1.4 g, 98%) as evidenced by congruent infrared spectrum and melting point.

Spiro[8′-carboxy-1′,2′,3′,4′-tetrahydronaphthalene-1′,3-4-methylsuccinimide] (9).

Imide 5a ($R^1 = CH_3$) (0.5 g, 1.96 mmoles) was dissolved in 10 mL of 1% potassium hydroxide. The solution was extracted with chloroform, the aqueous phase was acidified to pH 1 with 20% sulfuric acid and the resulting solid was collected to give 9 (0.39 g, 73%). Compound 9 was purified for analysis by recrystallization from aqueous ethanol: mp 259-262° (dec) (the 3° melting range observed for this acid and acid 8 is attributed to a diastereoisomeric mixture); ir 2.85-2.95, 3.05, 3.3-3.6, 3.7-3.9 (H-bonding and CH), 5.68 and 5.90 (imide carbonyls), 5.80 (acid carbonyl), and 6.29 μ (aromatic); pmr (DMSO-d_6) δ 9.14 (1H, singlet, acid proton), 7.44 (3H, multiplet, aromatic), 2.93 (3H, multiplet, methylene), 1.90 (4H, multiplet, methylene), and 0.88 (3H, doublet, J = 7.5 cps, methyl).

Anal. Calcd. for $C_{15}H_{14}NO_4$: C, 65.94; H, 5.49; N, 5.13. Found: C, 66.12; H, 5.58; N, 5.06.

Literature Cited

1. Campaigne, E., W. Roelofs and R.F. Weddleton, 1968. 3a,4,5,6-Tetrahydrosuccinimido[3,4-b]acenaphthen-10-one . A Potent Anticonvulsant. J. Medicinal Chem. *11*: 395-396.
2. Campaigne, E. and R.F. Weddleton, 1986. Substituted Derivatives of 3a,4,5,6-Tetrahydrosuccinimido[3,4-b]acenaphthen-10-one. Proc. Ind. Acad. Sci. *95:* 159-165.
3. Campaigne, E. and E.M. Yokley, 1980. Tetrahydropyrrolidoacenaphthene and Benzazapropellane Derivatives as Potential Analgetic and Narcotic Antagonists. Proc. Ind. Acad. Sci. *89*: 136-141.
4. Hauck, F.P. Jr., J. Demick and J. Fan, 1967. Preparation and Anticonvulsant Activity of Some Aryldialkylsuccinimides. J. Medicinal Chem. *10*: 611-614.
5. House, H.O., 1965. Modern Synthetic Reactions, W.A. Benjamin, Inc., New York. pp 170-173.
6. Koelsch, C.F., 1961. An Indone to Naphthol Ring Expansion. J. Org. Chem. *26*: 1003-1005.
7. Miller, C.A. and L.M. Long, 1953. Anticonvulsants. IV. An Investigation of α-(Substituted Phenyl)-Succinimides. J. Am. Chem. Soc. *75*: 6256-6258.

Who's Teaching Chemistry in Indiana High Schools?

MARIE HANKINS
Department of Chemistry
University of Southern Indiana
Evansville, Indiana 47712

Introduction

"The crisis in precollege science and mathematics education — so much in the news just four years ago — is over (7)." When I saw that statement I was very upset, but as I read the article, "Crisis Passes but Problems Remain For Precollege Science and Math," by Ward Worthy in the March 10th issue of *Chemical and Engineering News*, it became clear that Mr. Worthy was not serious about the problems in science and math education having been solved. In fact, since a crisis, by definition, does not drag on, the crisis must be past. However, I think nearly everyone will agree that the problems that provoked the crisis have not been solved despite quite a bit of press to the contrary.

Consider, for example, the kind of information that has been supplied to the American public. According to a table presented in the *Chemical and Engineering News* article but provided by the National Center for Educational Statistics in 1984, the shortage of chemistry teachers is only 1.9 per 1000 teachers and only 4.1% of all the chemistry teachers were not certified in 1984 at the secondary level (7). One does not consider this information to be too alarming at first. In fact, there does not appear to be much of a shortage or reason for concern. However, according to Mr. Worthy's article, perhaps there is no shortage of teachers in the classroom, but the question of competence in the classroom remains a big issue.

In July, 1986, the department of curriculum and instruction in the school of education at Indiana University published the results of the "Indiana Needs Analysis Project (1)." According to this survey 97.3% of the chemistry class sections are currently being taught by certified teachers. My question is, what does certified mean? The more I read and talk to various people, the more confused I become. Are these teachers certified in chemistry? If they really are certified to teach chemistry, are they qualified?

The executive summary of the Analysis Project indicates that certification does not necessarily mean that the teachers are qualified to teach chemistry. In fact, many of the principals interviewed by telephone admitted that some of the teachers would be replaced, if qualified applicants were available. As the report stated: "There are no data on the extent to which certified teachers are highly effective and thus conclusions about teacher certification do not imply any conclusions about the quality of instruction in Indiana (1)." Mr. Worth's article points out that about one-third of the science classes are being staffed by teachers who would otherwise be out of a job due to declining enrollments. Physical education teachers were mentioned as a large percentage of these "certified" teachers (7).

Most of the reports that have been published, such as the "ACS Report of the Task Force for the Study of Chemistry Education in the United States," indicated the need to strengthen the science curriculum in both elementary and secondary schools (5).

International studies such as the one reported in March, 1986, show the need for improving the math skills of our student population (6). American students scored lower in mathematics than those from a dozen other industrialized nations. "Americans only outperformed students from third world countries and Sweden (6)." The testing took place in 1982, but some of the results had still not been released when the article appeared in the newspaper. A quote from U.S. Secretary of Education, William Bennett, points out the problem: "It is distressing that our top kids (the test was administered to the top 5%) would come in last. But our children are capable. It's a question of what we are giving them, what they are studying? The Japanese don't use some sort of magic. They work harder at it (6)." I feel that the same situation exists in chemistry because we are experiencing similar problems with the quality of instruction.

Obviously, the need for improvement has been recognized. Governor Orr must be aware of the problem because, according to a newspaper article in November, 1986, he is advocating lengthening the school year (3). However, increasing the number of days in class is not going to solve the problem unless the teachers are qualified to teach in their subject area. In fact, the international study showed that American students are already receiving more hours of instruction than their counterparts in other countries (6). The curriculum in Japan and other top scoring European nations is more extensive and faster paced than in America but this requires qualified instructors.

Some people must recognize this fact because the position statement presented by the National Science Teachers Association suggests that "a minimum of 50 semester hours of coursework in one or more of the sciences, as well as supplementary study in closely related areas such as mathematics, statistics, and computer applications, should be required for preservice secondary science teachers (4). If one reads this carefully, it is obvious that even this statement is not strong enough. Suppose a student takes 24 hours in chemistry, 15 hours in biology, and 11 in geology, physics, or some other earth science. Even worse, suppose he/she takes 24 hours in biology, 15 in chemistry, and 11 in some other science. If I am correct in assuming that certification, even now, only requires 24 hours in a primary area and 15 in a supporting area and that one can teach in one's supporting area, then this means that chemistry can be taught by an education major with a primary area in biology and a supporting area in chemistry. Theoretically one can teach chemistry in high school having taken only two semesters of general chemistry and one or two semesters of organic chemistry. Since organic chemistry, if it is presented, should be a very small part of the first year of high school chemistry, the teacher is trying to teach high school chemistry having had essentially only general chemistry in college.

Results

The results of a survey that I conducted this past spring lead me to believe that this is typical about 50% of the time. Mailing the survey to 400 schools resulted in response from about 120 teachers. As one might expect, the majority of the responses were from males (78%) and from public high schools (89%). Most of the respondents had advanced degrees. As can be seen in Table 1, thirty-seven percent had a Master's degree and 15% had a Master's plus from 1-15 hours additional course work.

Looking at the years of teaching experience in Table 1, one finds that the responses were somewhat evenly distributed between respondents who had been teaching from 6-10, 11-15, and 16-20 years with slightly fewer from those in the 21-25 year category. The smallest percentage of responses came from the teachers who have been in the profession for 1-5 years. Although one cannot draw too many conclusions about the number of teachers actually in these categories, Mr. Worthy's article tends to substantiate the conclusion that many of our current science teachers are nearing retirement.

Only 37% of the respondents (Table 1) have degrees in chemistry. However, it is difficult to quantify what a degree in chemistry means. Some of the respondents indicated that they had a degree in chemistry when they had only taken approximately 20 hours of chemistry. Obviously, some of them listed a degree in chemistry when they probably had a degree in education with a primary or supporting area in chemistry.

Approximately 50% of the respondents indicated that they had taken a physical chemistry course. Unfortunately, they did not always indicate whether it was a one-semester or two-semester course or whether it was at the graduate or undergraduate level. Looking at the response leads one to believe that many of the respondents either took a one-

TABLE 1. Respondent Histories

	Degrees (Percent)	Years of Teaching (Percent)	
BS or BA	4.6	1-5	9.0
plus 1-15 hrs.	5.6	6-10	20.7
plus 16 or more	21.3	11-15	18.9
MA or MS	37.0	16-20	19.8
plus 1-15 hrs.	14.8	21-25	16.2
plus 31 or more	11.9	25 plus	15.3
ABD	1.9		

	Degree (Percent)
Chemistry	50.6
Biology	30.4
Other	19.0

Degree of Respondent Teaching First Year Chemistry

	Present (Percent)	Future (Percent)
Chemistry	50.6	45.0
Biology	30.4	27.5
Other	19.0	27.5

semester course or a two-semester course which was the equivalent of undergraduate physical chemistry, but they received graduate credit.

Assuming that all the respondents who said that they had a degree in chemistry really did, then approximately 51% (Table 1) of the first year chemistry courses and only 62% of the second year or advanced chemistry courses are being taught by people with a chemistry degree. The situation will deteriorate as the new science requirements are met. According to the survey, the percentage of first year courses that will be taught by people with chemistry degrees will fall to 45% next year (Table 1). Obviously, some people have already been told that they will have to teach chemistry in the future.

Questions concerning attendance at workshops, seminars, summer institutes and industrial experience revealed that about 52% of the teachers had attended seminars and workshops and that about 52% had attended summer institutes. A few of the teachers had some industrial experience.

Discussion

According to a newspaper article in September, 1986, a coalition of some of Indiana's largest teacher education schools have agreed that undergraduate teacher education programs should not be moved to the graduate level as suggested by recent national studies such as "Tomorrow's Teachers" and "A Nation Prepared: Teachers for the 21st Century" (a report of the task force on teaching as a profession) (2). If students were allowed to take most of their education courses in graduate school, then they could devote more of their time in undergraduate school to learning the subject matter in their primary and supporting areas and would be better prepared to teach these subjects. Given the evidence of the sad state of science education in this country, it is difficult to understand why these teacher education schools are opposed to the idea!

Literature Cited

1. Harty, H. and Kloosterman, P. 1986. Executive Summary of the Indiana Needs Analysis Project. Department of Curriculum and Instruction, School of Education, Indiana University.

2. Considine, Dan. Sept. 28, 1986. Elevation of Education is Opposed. The Sunday Courier and Press. Evansville, Indiana. October 1986.
3. "Orr Stresses Importance of Lengthening the School Year." Nov. 7, 1986. Evansville Courier, Evansville, Indiana.
4. Standards for the Preparation and Certification of Teachers of Science, K-12. National Science Teachers Association. Originally published in Science and Children. September, 1983 and the Journal of College Science Teaching. November, 1983.
5. Tomorrow: The Report of the Task Force for the Study of Chemistry Education in the United States. October, 1984.
6. U.S. Students Outscored by Most in Math Study. March 10, 1986. Evansville Courier, Evansville, Indiana.
7. Worthy, Ward. 1986. Crisis Passes but Problems Remain for Precollege Science and Math. Chemical and Engineering News. 64:7-12.

Solution Calorimetry Studies of Hydrogen Bonding in Aliphatic Alcohols

J.L. Kirsch and L.J. Lucchese
Department of Chemistry
Butler University
Indianapolis, Indiana 46208

Introduction

Alcohols in the pure state exist in a high degree of association (polymerized). This association results from hydrogen bonding at the hydroxyl site. If alcohols are placed in a nonhydrogen bonding solvent, such as heptane, the extent of alcohol association is concentration dependent. At low concentrations the alcohol will exist as unassociated (single) molecules, whereas at high concentration the molecules of alcohol will be associated. At intermediate concentrations, an equilibrium between single and associated molecules will exist (2,4).

If a pure alcohol is dissolved in a nonhydrogen bonding (inert) solvent such that the concentration of the resulting solution is low, the alcohol will be converted from the associated hydrogen bonded form to the unassociated nonhydrogen bonded form. The major contribution to the heat of this dissolving process, the enthalpy of solution, will then be the energy to break the hydrogen bonds for the associated alcohol. Studies reported in the literature indicate tha the enthalpies of solvation are minor in inert solvents (1). Since the dissolving process is primarily a hydrogen bond breaking process, the enthalpy of solution will be endothermic and will reflect the strength of the hydrogen bond between the alcohol molecules.

Experimental

Measurements of heats of solution were made in a Parr 1451 solution calorimeter by mixing neat alcohol with 100 mL of heptane solvent and recording the temperature change with a recorder thermistor system. The amount of alcohol used in each of the heat of solution experiments was chosen such that the concentration of the resulting alcohol-heptane solution was in the concentration range where unassociated (single) molecules exist. This concentration range for each alcohol was determined from concentration-dependent nmr data (2,4). Rapid exchange in the equilibrium between unassociated and associated alcohol molecules causes only one hydroxyl proton nmr line to be observed. The chemical shift of the hydroxyl nmr line is alcohol-concentration dependent. A plot of chemical shift versus concentration yields a sigmoid curve. The concentration range over which the alcohol exists as unassociated molecules was assumed to be that portion of the sigmoid curve parallel to the concentration axis at the low concentration limit.

Temperature measurements are the major source of uncertainty in the heat of solution values. In order for the resulting heptane-alcohol solution to be in the concentration range where unassociated alcohol molecules predominate, a small amount of alcohol (0.4 to 0.07 g) is mixed with the heptane, resulting in a small temperature change. All determinations were carried out at a 0.5 °C (50 mv range) full-scale expansion on the recorder. At a 0.5 °C recorder scale-expansion, one millimeter on the recorder paper which is near the lower limit of measurement is equal to 0.002 °C. Calculation of $\triangle$T from a temperature versus time curve by a standard Parr method (3) generated two significant digits.

The heat capacity of the calorimeter was determined by heat transfer from hot copper metal to the calorimeter. Hot copper metal was dropped into the calorimeter loaded with a 100-mL sample of heptane.

$$q_{\text{copper}} = - q_{\text{calorimeter}}$$

By knowing the specific heat of the copper, mass of the copper, initial and final temperatures of the copper, and initial and final temperatures of the calorimeter, one can calculate the heat capacity of the calorimeter.

$$q_{copper} = mass_{Cu}\, C_{Cu}\, (T_f\,(Cu) - T_i\,(Cu))$$

$$q_{calorimeter} = C_{calorimeter}\, (T_f\,(Cal) - T_i\,(Cal))$$

$$C_{calorimeter} = \frac{-\, mass_{Cu}\, C_{Cu}\, (T_f\,(Cu) - T_i\,(Cu))}{(T_f\,(Cal) - T_i\,(Cal))}$$

Table I summarizes the calibration data and calculations. Using C_{Cu} as 0.09305 cal/g deg (5), the average value for the heat capacity of the calorimeter was determined to be 67.6 cal/deg.

Table I. (Calorimeter Calibration)

Trial	mass of	$T_{i(Cu)}$	$T_f(Cu)$, $T_f(Cal)$	$T_i(Cal)$	$C_{calorimeter}$
1	9.9944 g	74.89 °C	22.25 °C	21.52 °C	$67.25\ \frac{cal}{deg}$
2	9.9948 g	74.89 °C	22.16 °C	22.45 °C	$67.98\ \frac{cal}{deg}$

Results and Discussion

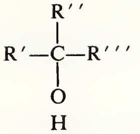
The strength of a hydrogen bond depends on the polarity of the molecules at the hydrogen-bonding site, on electrostatic effects, and on the ability of the molecules to approach each other (steric effects). In the series of alcohols chosen for this study (Table II), the polarity at the hydrogen-bonding site is nearly constant. The general form of the alcohol series is given by the formula in Figure 1. The variation of R′, R′′, and R′′′ for the series is listed in Table II.

Table II (Alcohol Series)

Alcohol	R′	R′′	R′′′
Benzyl alcohol	phenyl	hydrogen	hydrogen
4-methyl-2-pentanol	isobutyl	methyl	hydrogen
2-methyl-3-pentanol	isopropyl	ethyl	hydrogen
t-butyl alcohol	methyl	methyl	methyl
t-amyl alcohol	ethyl	methyl	methyl
2,4-dimethyl-3-pentanol	isopropyl	isopropyl	hydrogen
4-heptanol	n-propyl	n-propyl	hydrogen
3-methyl-3-pentanol	ethyl	ethyl	methyl
3-ethyl-3-pentanol	ethyl	ethyl	ethyl

Steric effects at the hydroxyl site clearly determine the strength of the molecular association in this series of compounds (2). As the size of the hydroxyl neighboring groups increases, the ability of the molecules to approach each other will decrease, and the strength

FIGURE 1. (general formula)



$$R'\text{—}\overset{\displaystyle R''}{\underset{\displaystyle \overset{|}{O}\atop H}{\overset{|}{\underset{|}{C}}}}\text{—}R'''$$

of the hydrogen bond will decrease. This decrease in hydrogen-bond strength with increase in steric hindrance at the hydroxyl site will result in a decrease in the heat of solution.

The alcohols are arranged into two groups for discussion, tertiary and secondary-primary. As expected, the heats of solution for the tertiary alcohols are generally lower (6.5 to 5.1 Kcal/mole) than those of the secondary-primary group (7.1 to 5.9 Kcal/mole). Tables III and IV summarize results of measurements of heats of solution for these groups. The alcohols are arranged in each table from high to low heats of solution.

The four tertiary alcohols listed in Table III have neighboring groups that vary from methyl, methyl, and methyl to ethyl, ethyl, and ethyl. The enthalpies of solution vary systematically with expected steric hindrance for this series of alcohols. It should be noted, however, that t-amyl and t-butyl alcohols have nearly the same heats of solution indicating that they have similar steric hindrance at the hydroxyl site (2,4).

TABLE III. (Enthalpies of Solution of Tertiary Alcohols)

Alcohol	Moles of alcohol per 100 mL of heptane	ΔT	ΔH*
t-butyl alcohol	.000928	− .089	6.5
t-amyl alcohol	.000849	− .080	6.4
3-methyl-3-pentanol	.00200	− .17	5.7
3-ethyl-3-pentanol	.00264	− .20	5.1

* heat of solution in Kcal/mole of alcohol

The first member of the group in Table IV (highest heat of solution, strongest hydrogen bond, and lowest steric hindrance at the hydroxyl site) is a primary alcohol with neighboring groups of phenyl, hydrogen, and hydrogen. The large phenyl group is compensated for by the two very small hydrogen atoms. The remaining members of this group are secondary alcohols with neighboring groups varying from methyl, isobutyl, and hydrogen to two n-propyl groups and a hydrogen atom. The order seems to be what is expected except possibly for 4-heptanol and 2,4-dimethyl-3-pentanol. One might expect neighboring isopropyl groups to hinder sterically the hydroxyl site more thatn the n-propyl groups because of branching next to the hydroxyl site. This does not, however, agree

Table IV. (Enthaplies of Solution of Primary and Secondary Alcohols)

Alcohol	Moles of Alcohol per 100 mL of heptane	ΔT	ΔH*
Benzyl alcohol	.00142	− .15	7.1
4-methyl-2-pentanol	.00297	− .30	6.8
2-methyl-3-pentanol	.00154	− .15	6.6
2,4-dimethyl-3-pentanol	.00348	− .32	6.2
4-heptanol	.00346	− .30	5.9

* heat of solution in Kcal/mole of alcohol

with the calorimetry results or some unpublished nmr hydrogen-bonding studies (4). One might argue that the longer n-propyl group hinders the hydroxyl site more than the branched isopropyl group because of its ability to reach the hydrogen-bonding site.

This study clearly shows that the heat of solution of a alcohol in a nonhydrogen-bonding solvent reflects the nature of the steric hindrance by neighboring groups at the hydroxyl site.

Literature Cited

1. Drago, R.S., N.A. Matwiyoff, 1968, Acids and Bases, D.C. Heath and Company, Lexington, Massachusetts, 56-60.
2. Kirsch, J.L., and D. Coffin, 1976, Infrared and NMR Studies of Hydrogen Bonding in Aliphatic Alcohols, Journal of Physical Chemistry, *80*, 2448.
3. Parr Solution Calorimeter Manual 154, Parr Instruments Co., Moline, Illinois.
4. Thomas B., and J.L. Kirsch, 1985, Variable Temperature NMR Studies of the Association of Aliphatic Alcohols in Dilute Carbon Tetrachloride Solutions, 101st Annual Indiana Academy of Science Meeting, Indiana University, unpublished work at this time — paper given.
5. West, 1981, CRC Handbook of Chemistry and Physics, CRC Press, Boca Raton, Florida, 61, D63.

An Ab Initio Molecular Orbital Calculation on Aromatic-tetracyanoethylene Charge Transfer Complexes

J.L. Kirsch and B.F. Volkman
Department of Chemistry
Butler University
Indianapolis, Indiana 46208

Introduction

One of the first steps in carrying out a MO calculation is to choose a set of atomic orbitals, a basis set, that is thought to best describe the bonding in the complex. The molecular orbital wavefunctions are then approximated by taking a linear combination of the atomic orbitals in the basis set.

$$\psi_i = \Sigma\, C_{ik}\ X_k \qquad \text{(LCAO)}$$

where

ψ_i = molecular orbital wave functions
C_{ik} = atomic orbital mixing coefficients (eigenvectors)
X_k = atomic orbital wave functions

The best molecular orbital wavefunctions are determined by minimizing the energy with respect to the atomic orbital mixing coefficients. This minimizing process, variational theory, results in the formation of n equations and n unknowns.

$$C_{ik}\ (H_{jk} + E_i\ S_{jk}) = 0$$

where

$$H_{jk} = \int X_j\ H\ X_k\ dt$$
$$S_{jk} = \int X_j\ X_k\ dt$$

In order for the above system of equations to have solutions other than the mixing coefficients being equal to zero, the so called secular determinant must be zero.

$$\det(H_{jk} + E_i\ S_{jk}) = 0$$

A number of methods are used to evaluate the integrals in the secular determinant. Huckel theory assigns alpha to H_{jj}, beta to H_{jk}, zero to S_{jk} when j is not equal to k, and 1 to S_{jk} when j is equal to k, and the energies are determined in terms of these parameters (2). Semiempirical methods use experimental data, VOIE, to approximate the H_{jj}, and a number of other approximate methods to determine S_{jk} and H_{jk} (2). The ab initio method used in the Gaussian 80, G80, program evaluates the integrals without the use of exp erimental data.

The G80 program is based on the Hartree Fock method (3). The Hartee Fock operator that is used to determine the MO wavefunctions is also dependent on the MO wavefunction. This operator-wavefunction dependence, therefore, requires an iterative process for the Hartree Fock type calculation. A set of MO wavefunction must be guessed, and the Hartree Fock operator evaluated. The Hartree Fock operator is then used to determine a new set of MO wavefunctions and their energies. This new set of MO wavefunctions, called the first improved set, is then used to calculate a new Hartree Fock operator and a second improved set of MO wavefunctions. This process is continued until a consistent set of wavefunctions and energies are obtained, a self consistent field.

Calculations

The origin of the G80 program is J. Pople, et al. at Carnegie-Mellon University; however, the program has gone through some evolution. The version used in this calculation is the result of the work done by U.C. Singh and P.A. Kollman at the University of California-San Franciso. The major program input parameters for the calculation are the nature basis set and the coordinates of each atom. The G80 program offers several basis set options (minimal option, extended option, and the option to enter functions from outside the program). A minimal basis set containing core and valence Slater type gaussian atomic orbital functions (STO-NG) on each atom was chosen for this calculation. Table 1 summarizes the basis set. The gaussian nature of the atomic orbital functions allows the program to compute the two electron multicenter integrals with greater ease (4). The coordinates of each atom were calculated from standard bond length and angles (1).

TABLE 1. Gaussian 80 Limited Basis Set (STO-3G)

Number of Atoms in the Complex	22
Number of Electrons in the Complex	106
Number of Atomic Orbitals in the Basis Set:	
6 benzene carbons (1S, 2S, 2PX, 2PY, 2PZ)	6×5 = 30
6 benzene Hydrogens (1S)	6×1 = 6
6 TCNE carbons (1S, 2S, 2PX, 2PY, 2PZ)	6×5 = 30
4 TCNE nitrogens (1S, 2S, 2PX, 2PY, 2PZ)	4×5 = 20
Total Atomic Orbitals in the Basis Set	86

Results and Discussion

The tetracyanoethylene-benzene charge-transfer complex is described in the literature as a coplaner sandwich type complex formed through the donation of the pi electron density of the benzene to the pi antibonding orbitals of the tetracyanoethylene (3). The complex contains 22 atoms and 106 electrons. The G80 calculations were carried out for both the triplet and the singlet states of the complex at various benzene tetracyanoethylene intermolecular distances. The results reported in this paper are for the intermolecular distance, 2.27 angstrom, that yielded agreement between E)total, triplet) - E(total, singlet) and the uv charge transfer band at 385 nm. This method of determining the intermolecular distance is an over simplification of the problem; however, the intermolecular distance determined in this manner is near the value previously reported (1). A study using the extended basis set and the coordinate optimization options is now underway.

The approximate nature of each molecular orbital was determined by examining the magnitudes of the eigenvectors for each AO in each MO. Figure 1 gives the energies in Hartree units and the approximate description of seventy of the eighty-six molecular orbitals generated by the eighty-six AO basis set. The first sixteen molecular orbitals were determined to be primarily nonbonding S type orbitals and were omitted from the diagram for clarity. For the singlet state, the first fifty-three molecular orbitals (total electrons / 2) are doubly populated with electrons, and molecular orbital number 54 will be the unoccupied orbital with the lowest energy. Figure 1 shows that there is a significant break in energy between the populated MO 53 (Energy of 53 < 0) and the unoccupied MO 54 (Energy of 54 > 0). It should also be noted that highest energy occupied and lowest energy unoccupied molecular orbitals are pi in nature. Finally, examination of the eigenvectors for molecular orbitals 54 and above shows more antibonding character than those molecular orbitals 53 and below.

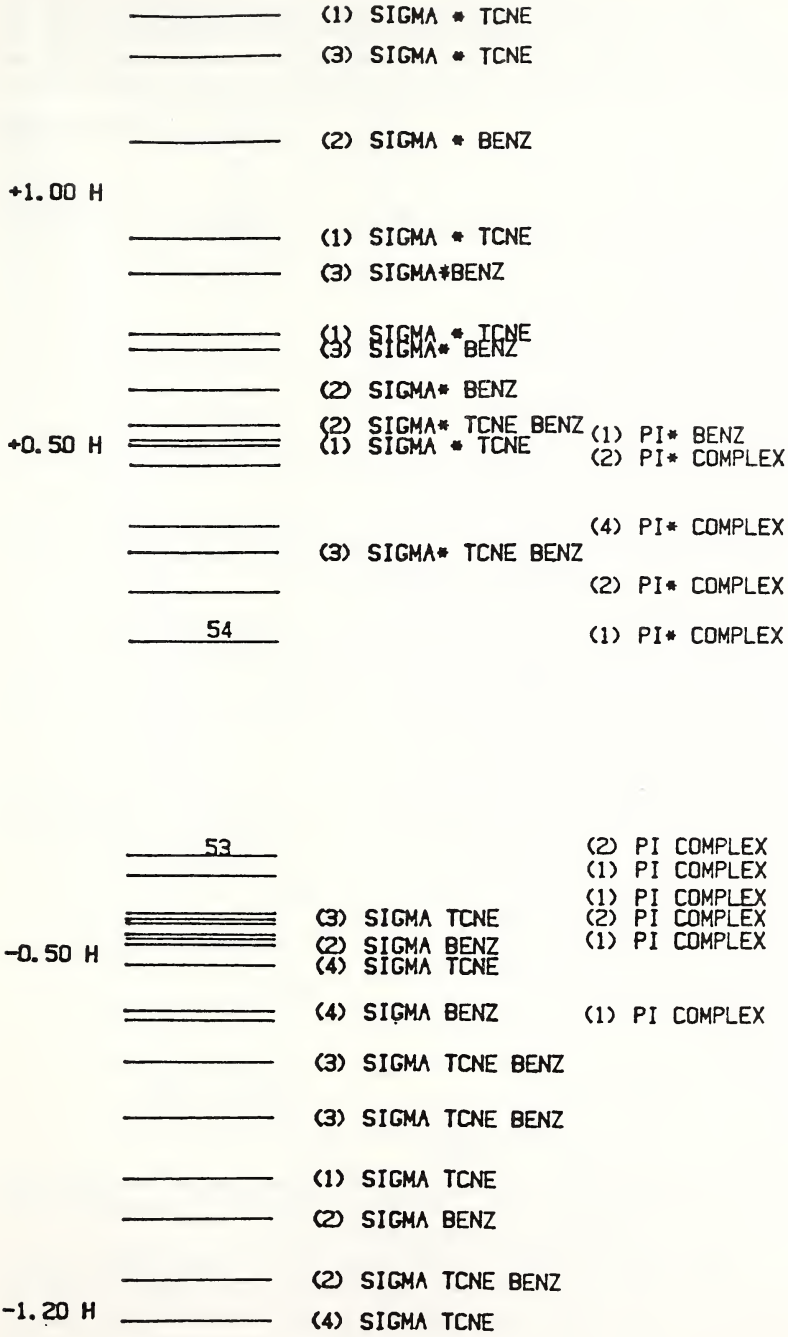


FIGURE 1. G80 MO Energy Level Diagram

Figure 2 is a MO energy level diagram of the pi molecular orbitals near the occupied-unoccupied interface for both the triplet and singlet state. This diagram gives the G80 calculation's description of the singlet to triplet electronic transition. Table 2 lists the eigenvectors for MO 51 and MO 54 which are involved in the singlet to triplet transition.

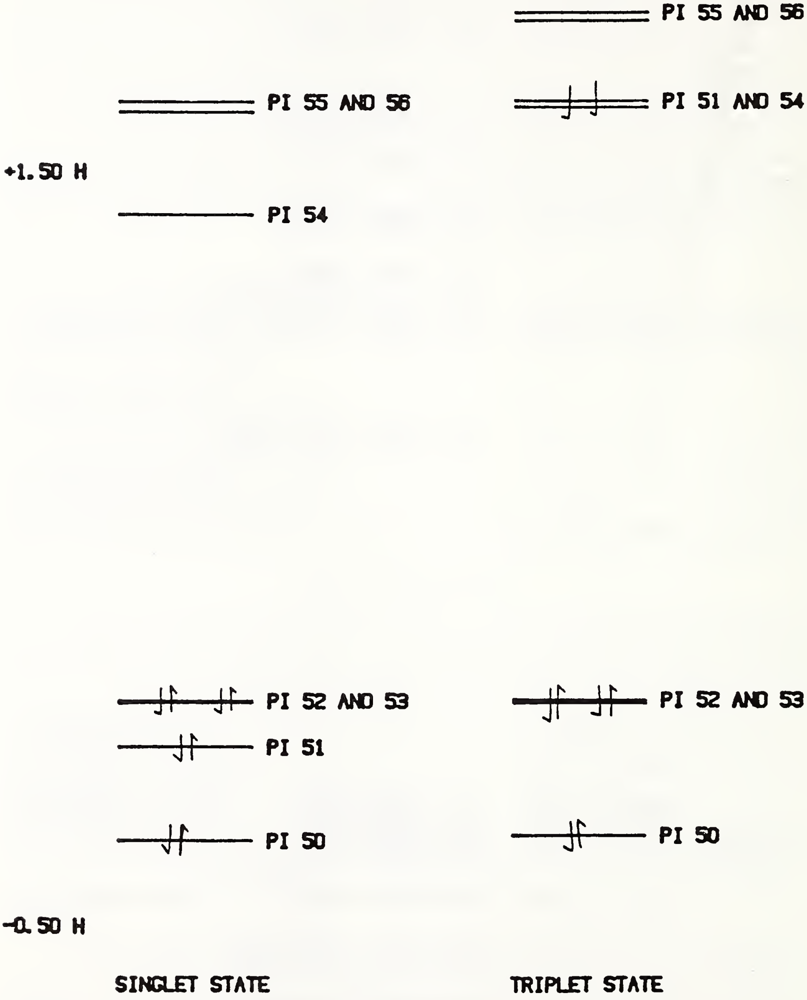


FIGURE 2. Pi MO Energy Level Diagram

The atom numbering system for these eigenvectors is given in Figure 3. Drawings of MO 51 and MO 54 based on these eigenvectors are shown in Figure 4. These calculation results say that the lowest energy electronic transition is pi to pi*.

The results of the Mulliken population analysis for the singlet state are listed in Table 3. The column labeled total charge is the G80 calculation's assignment of the electron density to each atom in the complex. The numbers in the net charge column are the difference in total charge and the normal valence state of the atom (C-6, H-1, N-7). It is interesting to note that the sum of net charges on benzene and tetracyanoethylene

Table 2. Eigenvectors for 2PZ (pi type) Atomic Orbitals (singlet)

Atom		MO # 51	MO # 54
Benzene	C1	0.064	−0.183
Benzene	C2	0.106	−0.103
Benzene	C3	0.106	0.103
Benzene	C4	0.064	0.183
Benzene	C5	0.106	0.103
Benzene	C6	0.106	−0.103
TCNE	C13	0.496	0.591
TCNE	C14	0.496	−0.591
TCNE	C15	−0.142	−0.153
TCNE	C16	−0.142	−0.153
TCNE	N17	−0.276	0.282
TCNE	N18	−0.276	0.282
TCNE	C19	−0.142	0.153
TCNE	C20	−0.142	0.153
TCNE	N21	−0.276	−0.282
TCNE	N22	−0.276	−0.282

indicates a transfer of 0.173 electrons from benzene donor to the tetracyanoethylene acceptor. Clearly, the results of this study are consistent with the accepted notion that a charge transfer complex is formed between these two compounds.

Acknowledgments

The authors wish to thank the Holcomb Research Institute and the Butler University Academic Grants Committee for their funding of this project. The authors also wish to thank Nick Vesper and Teresa Velasquez of the Butler University Computer Center for their valuable help with the VAX computer system.

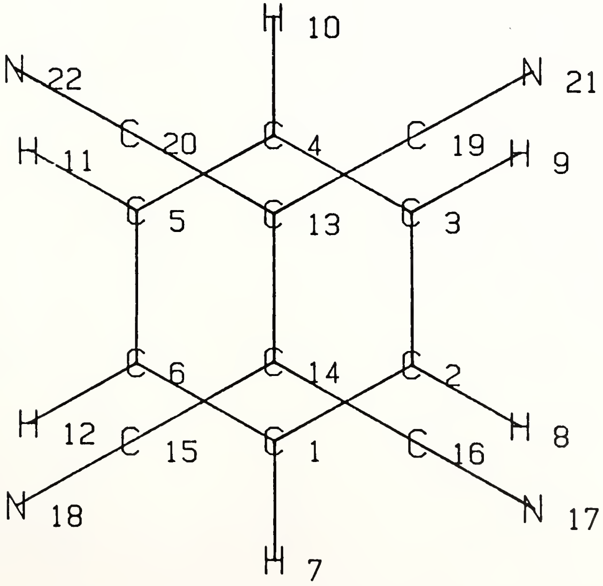
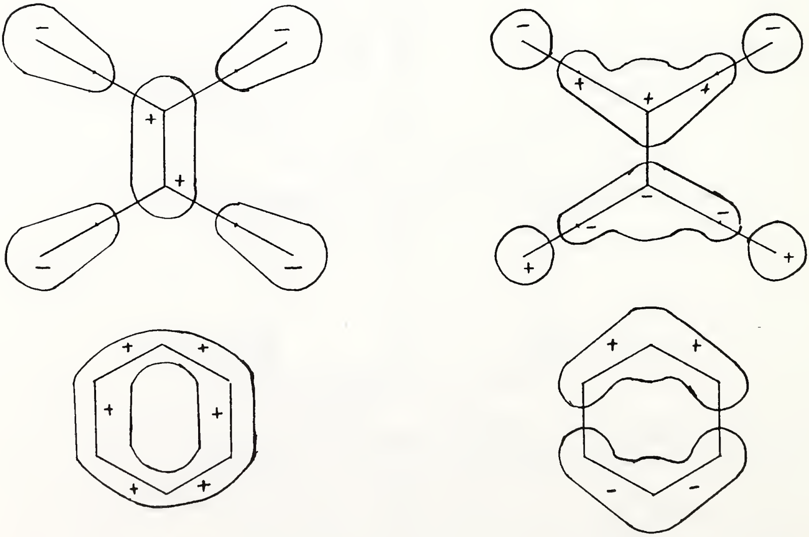


Figure 3. Atom Numbering System

TABLE 3. Atomic Charge from Population Analysis (Singlet State)

Atom		Total Charge		Net Charge
Benzene	C1	6.0578		−0.0578
Benzene	C2	6.0656		−0.0656
Benzene	C3	6.0656		−0.0656
Benzene	C4	6.0578		−0.0578
Benzene	C5	6.0656		−0.0656
Benzene	C6	6.0656		−0.0656
Hydrogen	H7	0.9118		0.0882
Hydrogen	H8	0.9063		0.0937
Hydrogen	H9	0.9063		0.0937
Hydrogen	H10	0.9118		0.0882
Hydrogen	H11	0.9063		0.0937
Hydrogen	H12	0.9063		0.0937
			Total	0.173
TCNE	C13	5.9463		0.0537
TCNE	C14	5.9463		0.0537
TCNE	C15	5.9135		0.0865
TCNE	C16	5.9135		0.0865
TCNE	N17	7.1566		−0.1566
TCNE	N18	7.1566		−0.1566
TCNE	C19	5.9135		0.0865
TCNE	C20	5.9135		0.0865
TCNE	N21	7.1566		−0.1566
TCNE	N22	7.1566		−0.1566
			Total	−0.173



MO # 51

MO # 54

FIGURE 4. MO Drawings

Literature Cited

1. Kirsch, J.L., S.G. Lieb, M.D. Cisneros, 1984, A SCC MO Calculation on Tetracyanoethylene-benzene Complex, Proceedings of the Indiana Academy of Science for 1984, 94, 181-185.
2. McGlynn, S.P., L.G. Vanquickenborne, M. Kinoshita, and D.G. Carrol, 1972, Introduction to Applied Quantum Chemistry, Holt Rinehart Winston, New York, N.Y., 97-140.
3. Mobley, M.J., K.E. Rieckhoff, and E.M. Voigt, 1978, Spectroscopic Studies on the Conformations fo Electron Donor Acceptor Complexes of Tetracyanoethylene, J. Physical Chem., 82, 2005-2012.
4. Schaefer, H.F., The Electronic Structure of Atoms and Molecules — A Survey of Rigorous Quantum Mechanical Results, Addison Wesley, Reading, Mass., 6-78.

A Study of the Coordination Compounds of Some Transition Metals with 2-amino-2-methyl-1,3-propanediol

Joseph R. Siefker and Lester A. Page, Jr.
Department of Chemistry
Indiana State University
Terre Haute, Indiana 47809

Introduction

S.P. Datta and A.K. Grzybowski used a glass electrode to determine equilibrium constants for complexes of Ag^+ with 2-amino-2-methyl-1,3-propanediol (1). They found a value of 3.20 for log K_1 and a value of 3.66 for log K_2. We have used spectrophotometric data to determine the stepwise formation stability constants and the molar absorptivities for the complexes of Co^{2+}, Mn^{2+}, and Ni^{2+} with 2-amino-2-methyl-1,3-propanediol.

Experimental

A Cary Model 17 spectrophotometer was used to record precise absorbance measurements on solutions at 25 ° C. The 2-amino-2-methyl-1,3-propanediol was obtained from the Aldrich Chemical Company. The metal ion solutions were prepared from G. Frederick Smith Chemical Company $Co(Cl0_4)_2 \cdot 6H_20$, $Mn(Cl0_4)_2 \cdot 6H_20$, and $Ni(Cl0_4)_2 \cdot 6H_20$ reagents.

Spectrophotometric data were obtained from freshly prepared solutions. Separate aqueous stock solutions containing ligand and metal ion were prepared. Portions of the stock solutions were mixed with water for dilution to prepare a series of solutions 0.1-0.8 mM in Co^{2+} and 0.1-5.0 mM in ligand, a series 0.4-1.0 mM in Mn^{2+} and 0.4-3.2 mM in ligand, and a series 0.2-0.8 mM in Ni^{2+} and 0.2-6.0 mM in ligand. The solutions were mixed well, and absorption spectra were obtained as soon as possible after mixing. No inert electrolyte was added to raise the ionic strength. The solutions had low ionic strengths (0.3-3.0 mM). Approximately ninety solutions were prepared and many spectra were obtained.

Stability constants and the molar absorptivities at six wavelengths for Co^{2+}, six wavelengths for Mn^{2+}, and five wavelengths for Ni^{2+} complexes were calculated with the computer program of Lingane (2).

Results and Discussion

The values for the stability constants are given in Table 1 and those for the molar absorptivities in Tables 2-4. The equilibrium constants were highest for the Mn^{2+} com-

Table 1. Values of Stability Constants for Complexes of the Metal Ions with the Ligand

	Co^{2+}	Mn^{2+}	Ni^{2+}
log K_1	4.28	4.78	4.54
log K_2	2.87	3.78	2.71

Table 2. Values of Molar Absorptivities (ϵ,L mole^{-1} cm^{-1}) for Complexes of Co^{2+} with 2-amino-2-methyl-1,3-propanediol

λ,nm	210	220	230	240	250	260
$^{\epsilon}CoL^{2+}$	525	423	321	243	163	88
$^{\epsilon}CoL_2^{2+}$	2771	2260	2097	1852	1590	1361

TABLE 3. Values of Molar Absorptivities (ϵ, L mole^{-1} cm^{-1}) for Complexes of Mn^{2+} with 2-amino-2-methyl-1,3-propanediol

λ,nm	335	350	370	390	410	430
$\epsilon_{MnL^{2+}}$	703	591	475	368	294	227
$\epsilon_{MnL_2^{2+}}$	1545	1362	1156	994	863	761

TABLE 4. Values of Molar Absorptivities (ϵ,L mole^{-1} cm^{-1}) for Complexes of Ni^{2+} with 2-amino-2-methyl-1,3-propanediol

λ,nm	210	220	230	240	250
$\epsilon_{NiL^{2+}}$	575	349	196	102	54
$\epsilon_{NiL_2^{2+}}$	2509	1369	700	341	113

plexes. The first constant was higher for Ni^{2+} than for Co^{2+}. The second constant was higher for Co^{2+} than for Ni^{2+}. The values of log K_1 for Co^{2+}, Mn^{2+}, and Ni^{2+} were higher than the value of 3.20 found by Datta and Grzybowski (1) for Ag^+; while the values for log K_2 for Co^{2+} and Ni^{2+} were lower than the value of 3.66 found by them for Ag^+.

The molar absorptivities for the first complex were highest for Mn^{2+} and lowest for Ni^{2+}. The molar absorptivities for the second complex were highest for Co^{2+} and lowest for Ni^{2+}.

Literature Cited

1. Datta, S.P., and A.K. Grzybowski, 1959. The stability constants of the silver complexes of some aliphatic amines and amino-acids. Jour. Chem. Soc. (London). 1091-1095.
2. Lingane, P.J., and Z.Z. Hugus, Jr., 1970. Normal equations for the Gaussian least-squares refinement of formation constants with simultaneous adjustment of the spectra of the absorbing species. Inorganic Chem. 9:757-762.

ECOLOGY

Chair: George R. Parker
Department of Forestry and Natural Resources
Purdue University
West Lafayette, Indiana 47907 (317) 494-3574

Chair-Elect: James R. Aldrich
Department of Natural Resources
605 B State Office Building
Indianapolis, Indiana 46204 (317) 232-4078

ABSTRACTS

Mechanisms of Reproductive Isolation in Two Sympatric Stickleback Species. Charles L. Baube, Indiana University, Bloomington, Indiana 47405.——Throughout its range the Black-spotted Stickleback (*Gasterosteus wheatlandi*) is sympatric with the larger congeneric *G. aculeatus.* Though able to hybridize, reproductive isolation is maintained by a presumed behavioral mechanism that is, as yet, unclear. An experiment was undertaken to determine the extent to which male courtship maintains this isolation. Pairwise presentations to *G. wheatlandi* males of proportionally gravid female dummies of varying length shows that 1) males preferentially court the larger of the two dummies, and 2) preference strengths are related to the differences in length between the dummies.

These results indicate that *G. wheatlandi* male courtship preferences may be maladaptive because choice for the larger female often means the wrong species. Further discussion will focus on other factors that may be acting to achieve reproductive isolation between these species.

Notes on the Life History of the Intertidal Spider, *Paratheuma insulana* (Araneae; Desidae). James W. Berry, Department of Biological Sciences, Butler University, Indianapolis, Indiana 46208.——*Paratheuma insulana* is an intertidal spider previously found in the Caribbean region, and this is the first record of a member of the Family Desidae from the United States. This is also the first record of the male of the species. *Paratheuma insulana* inhabits broken coral rubble just below the highest tide mark. In the laboratory both males and females mature in about 6 months after passing through 6-8 instars. At about weekly intervals females produce cocoons containing an average of 20 eggs. Some females have produced as many as 25 cocoons. Adults have survived for as long as 14 monhts. They feed on an intertidal isopod found in decaying seaweed.

Bimodal Size Distributions of Even-aged Populations: Their Origins and Effects on Community Structure in Larval Salamanders. Spencer A. Cortwright, Department of Biology, Indiana University, Bloomington, Indiana 47405.——Bimodal size distributions of even-aged populations can arise due to dominance and suppression (in plants) and cannibalism (in fish). Some larval Jefferson salamander (*Ambystoma jeffersonianum*) populations develop bimodal size distributions. Field evidence shows that bimodal distributions of Jefferson salamanders are only found in ponds or experimental enclosures which have sizeable wood frog (*Rana sylvatica*) populations. I propose the following mechanism for the origin of bimodality in Jefferson salamander larvae. The initial size distribution of salamanders is log-normal due to variation in hatchling size and chance early feeding opportunities. Later, individuals in the right tail of the distribution are able to exploit wood frog tadpoles, a new and very profitable resource. These individuals subsequently grow much faster than those feeding mainly on zooplankton.

Early Root Development of Planted Red Oak Seedlings in Clearcut Forest Openings. L.D. FARLEE AND B.C. FISCHER, Purdue University, West Lafayette, Indiana 47907.——Northern red oak seedlings (1-0) planted spring 1986 in 3 clearcut forest openings on Yellowwood State Forest were excavated during the first growing season (early August) to evaluate root regeneration. Four seedlings per treatment block, stratified through three initial size classes, were randomly selected for excavation, giving a total of 36 seedlings sampled. Root regeneration characteristics were compared to seedling size, growth characteristics, chemical properties and quality of planting. Root regeneration capacity, and average length and weight of root regeneration were greatest in the largest seedling size class. The smallest seedlings had fewer primary lateral roots than the two larger size classes. Root initiation sites were found to be primarily where roots were injured during root pruning. Total above ground height and the number of growth flushes before excavation were greatest in the largest size class. The results of poor planting technique, air pockets around the root at the time of seedling excavation, were reduced shoot growth and root regeneration.

Aquatic Invertebrates and Phytoplankton of Miller Woods Ponds, Indiana Dunes National Lakeshore. ANGEL V. GOCHEE AND RICHARD L. WHITMAN, Department of Biology, Indiana University Northwest, Gary, Indiana 46408.——An organismal survey of the interdunal ponds of Miller Woods was made during 1984-85. These ponds exist in ridge and swale terrain, and may be classified as mature to presenescent. Study ponds were generally shallow and contained vernal, aestival and semipermanent water. Most of the ponds are natural; however, some ponds may have been created or deepened to supply fill for elevated railroad beds. Phytoplankton was dominated by diatoms (*Frustulia*, *Fragillaria* and *Tabellaria*) and *Pandorina.* Dominant zooplankton included cladocerans, *Ceriodaphnia* and *Daphnia*; copepods, *Eucyclops* and *Mesocyclops* and the sarcodine, *Arcella. Hyalella*, chironomids, *Sphaerium*, *Crongonyx*, *Lymnea*, caddisflies, *Asellus* and *Caenis* dominated lower trophic level benthos; while tabanids, dytisids, odonates and phantom midges dominated higher trophic levels. No fish were observed in any of the ponds.

Two Decades of Change in the Forest Structure of Virgin Coast Redwoods (*Sequoia sempervirens*) D. Don (Endl.) in Stout Grove, Del Norte County, California. MARION T. JACKSON, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809 and D. BRIAN ABRELL, Division of Nature Preserves, Indiana Department of Natural Resources, Indianapolis, Indiana 46204.——In 1966 the trees of a 3.2 hectare section of Stout Grove, a virgin stand of coast redwoods located along the Smith River in Del Norte County, California, were mapped at a 1:33 scale. In August 1986 all trees $\geq$ 10 cm dbh were remeasured to determine growth, in growths and mortality of individual trees. Ten tree species comprise the stand with redwood (the only canopy tree) contributing nearly 90% of stand density and over 99% of stand basal area. This excellent high quality first growth redwood stand appears to be near equilibrium with growth and ingrowth basal area closely approximating that lost due to mortality.

Evolution of Reproductive Isolation in Two Species of Toad. JANE F. KOSKA, Department of Biology, Indiana University, Bloomington, Indiana 47405.——The American toad (*Bufo americanus*) and Fowler's toad (*B. fowleri*) are sympatric throughout much of eastern North America and often hybridize. Blair (1941) found that Bloomington, IN area populations were hybridizing in 1940. Jones (1973) suggested that following some initial introgression, hybridization had ceased by 1970. In 1986, males were collected from three sites, including those used by Blair and Jones. Seventeen morphological characters were recorded. A discriminant analysis distinguished two groups corresponding to the two species. The analysis accounted for all variance using 8 characters. No intermediates were detected. These results suggest that no effective hybridization is occurring. Further research will incorporate call parameters and more extensive sampling.

Ginn Woods: An Undisturbed Virgin Forest in East-central Indiana. MARK S. MCCLAIN, Ball State University, Muncie, Indiana 47306.——The edaphic and pedologic factors of forest soils and their influence on the naturally occurring climax vegetation in an old-growth forest in east-central Indiana, known as Ginn Woods, were examined. The tree species composition on the respective soils in the woods was studied. The extent of disturbance and history of the woods was examined. It was found that the soils were undisturbed and it appears that there has never been any fire, grazing, or timber taken from the northern portion of the woods. It was concluded that the northern portion of Ginn Woods is an undisturbed, virgin forest and is best classified as a sugar maple-American beech-slippery elm association.

Microcosm Acid Rain Experiments with Water from Oriole Pond, Perry County, Indiana. THOMAS S. MCCOMISH, Ball State University, Muncie, Indiana 47306.——The potential impacts of acid rain on the alkalinity, conductivity, and pH of surface waters in Perry County of southern Indiana were investigated in microcosm experiments with water from Oriole Pond. Microcosm models simulated systems with one-third annual volume replaced with simulated acid rain (SAR) at pH 5.6, 4.5, 4.0, and 3.5.

Microcosms with water only after treatment with SAR showed significant declines in alkalinity (15-33 ppm) and conductivity (29-38 umhos). A significant pH decrease of 0.2 units occurred with SAR at pH 4.0 and 3.5. Other microcosms with water and substrate material had greatly lowered initial values for alkalinity and pH compared to those with water only due to substrate influence. Addition of SAR resulted in a significant decrease in conductivity (22-35 umhos) in all SAR tests. A significant pH decrease of 0.4 units occurred at pH 3.5. Alkalinity was so low in the microcosms at the initiation of experiments (0.6-1.2 ppm), due to the low pH levels (5.5-5.9), that no changes were measurable with addition of SAR regardless of pH level.

These results reveal Oriole Pond water is vulnerable to change with addition of acid rain. Since the pH of rain in this area is about 4.5, models indicate a likely negative impact of acid rain on surface waters with low alkalinity in this area of Indiana.

More on: Do Tadpoles Die for Their Siblings? CRAIG E. NELSON, SCOTT J. BARTON AND DAVID F. PARKHURST, Indiana University, Bloomington, Indiana 47405.——If same-age, conspecific tadpoles are grown together, the largest tadpole usually grows rapidly but the growth of the smaller tadpoles is retarded. The extent of this disparity increases with increased crowding. At the extreme, smaller tadpoles die and are eaten by the others. To assess the evolutionary significance of this pattern, we examined tadpoles of four species for differences in growth between groups of siblings and non-siblings. There were significant differences in each species but the pattern differed among species. In wood frogs siblings are smaller, in bullfrogs siblings are larger, in the other two species the pattern changes with density. In American toads, the growth of the largest tadpole was disproportionately accelerated. Toads and wood frogs were tested for differences in degree of association between sibling groups and non-sibling groups. Sibling toads spend more time together. These differences in growth and behavior are concordant with ecological differences among the species.

Pollination, Nutrient and Energy-limited Female Reproductive Success in *Catasetum ochraceum* Lindl. (Orchidaceae). GUSTAVO A. ROMERO, Department of Biology, Indiana University, Bloomington, Indiana 47405.——*Catasetum* L.C. Rich. is one of about 4 known orchid genera with separate staminate ("male") and pistillate ("female") flowers. Evidence indicates that female reproductive success is pollination, nutrient and energy-limited. First, hand pollinated flowers set more fruits than undisturbed flowers and only a third of the undisturbed inflorescences set fruits. Second, fruits contain a considerable proportion of the plant nutrient reserves, and most plants bearing fruits one year bear male flowers or no flowers at all the next. Finally, only plants exposed to sunlight bear pistillate flowers, suggesting that only those plants able to sustain high photosynthetic rates can bear fruits.

Aspects of the Biology of *Carex woodii* Dew. (Cyperaceae). Paul E. Rothrock, Taylor University, Upland, Indiana 46989.——*Carex woodii*, a sedge of rich, dry woodlands, is endangered with extirpation in Illiois, Indiana, and Ohio. In much of its range, this species is associated with moraine deposits of the Wisconsin glaciation; however, eastern populations also occur in unglaciated regions of diverse geologic history. In N-central Indiana, *C. woodii* blooms over a 14 to 20 day period in early April. According to field observations, female flowers expand 1 or more days before male flowers of the same culm. Unpollinated stigmas can remain receptive for approximately 7 days. Filaments of mature anthers elongate at night. Pollen release begins from ca. 9 AM to early afternoon depending upon temperature and humidity and is completed within 4 hours. *C. woodii* produces well-formed, abundant pollen (> 30,000:1 = pollen:ovule ratio) which is eaily carried by wind. Bagged inflorescences were self-compatible and non-apomictic. In the 1986 season, fruiting was sparse with only 8 of 30 sample plots bearing fruiting culms.

Aggression versus Courtship in Sticklebacks: The Role of Habituation. WILLIAM J. ROWLAND, Department of Biology, Indiana University, Bloomington, Indiana 47405.-——Interaction of courtship and territorial aggression in male threespine sticklebacks (*Gasterosteus aculeatus*) was investigated by presenting dummy females to subjects nesting alone (Solitary Situation) and in view of males in adjacent tanks (Rival Situation). During dummy presentation subjects engaged in more courtship and nest activity when solitary than when in the rival situation. Subjects in the latter situation instead spent most time during dummy presentation threatening and biting rivals. Thus, the presence of a rival can interfere with another male's courtship, by distracting the latter's attention from the dummy female or by eliciting in him an aggressive state that interferes with the expression of sexual tendencies. With prolonged, constant view of rivals, subjects spend less and less time with them but increasingly more time courting the dummy during presentations. This decrease in aggression is presumed to result from habituation to the neighboring males. Thus, habitation can play an important role in mitigating aggressive response to familiar rivals, thereby allowing males to devote more time to courtship and nesting activities. This study was supported, in part, by an Indiana Academy of Science Research Grant to the author.

Analysis of Playback-record Responses in the Male Cricket Frog, *Acris crepitans*. WILLIAM J. SHEPHERD AND STEPHEN A. PERRILL, Department of Biological Sciences, Butler University, Indianapolis, Indiana 46208.——A series of playback-record experiments was performed with male cricket frogs. An unsolicited call was recorded for each subject. Immediately following, a conspecific mating call was broadcasted while the subject's response call was simultaneously recorded. The response to the broadcasted call differed from the unsolicited call in structure and sound pressure level. When *Hyla versicolor* calls were broadcasted as controls, one of 12 *Acris* responded.

Disturbance Effects in Oak Dominated Forests of Central Indiana. PAUL T. SHERWOOD AND GEORGE R. PARKER, Purdue University, West Lafayette, Indiana 47907.——Gap phase tree replacement patterns were studied in an old-growth deciduous forest located in east central Indiana and in a second-growth deciduous forest in west central Indiana. Both forests are dominated by *Quercus* species with understories comprised most of late seral, shade tolerant species such as *Acer saccharum*. Diameter distributions by species for individuals within the five gaps sampled suggest that the midtolerant *Quercus* species are not replacing themselves in the small canopy openings created by the fall of one or two canopy dominants. The effects of agricultural abandonment on secondary forest edge succession were studied in another *Quercus* species dominated old-growth forest located in west central Indiana. Thirty-five percent of all stems sampled on this site are *Fraxinus* spp. while sixteen percent are *Quercus palustris*. The effect of strip clearcutting on forest tree regeneration pattern was also studied in a fourth *Quercus* species dominated forest in west central Indiana. Five year results indicate that while greater than 700 stems per hectare of *Quercus* spp. individuals were found in the clearcut, these stems are in a subordinate position to *Acer saccharum* and *Ulmus* species.

The Relationship between Weed Community Development and Tillage Type in Grant County, Indiana. EDWIN R. SQUIERS AND LEONARD H. ROBBINS, Departments of Biology and Environmental Science, Taylor University, Upland, Indiana 46989.——The relationship between tillage type and weed community development was investigated on the experimental fields of the Miller Purdue Agricultural Center 2 miles east of Upland, Indiana. Beginning in 1985, the conservation tillage techniques of paraplow and no-till were compared with traditional moldboard plowing on a pair of 360 ft. × 1200 ft. fields. A randomized complete block design was established with four replicates of each of the three tillage types. The fields were planted in corn in 1985 and rotated to soybeans in 1986. The weed community was assessed each year using four strip samples of ten plots each within each of the replicates yielding 480 plots across the experimental design. Analysis of variance was used to compare weed species frequency data within and between tillage types. The results indicate that some differences in the weed community do develop in response to each tillage type. These differences, though significant, were not reflected in lowered yields. This study suggests that, in terms of crop production, the weed control problems often associated with conservation tillage methods may be more a matter of perception than reality.

The Assessment of Interactions among Ovipositing Goldenrod Gall Flies, *Eurosta solidaginis*, Fitch. ROD WALTON, Department of Biology, Indiana University, Bloomington, Indiana 47405.——The interaction assessment method of estimating density-dependent interactions between conspecifics and between members of different species is outlined and applied to a population of goldenrod gall flies, *Eurosta solidaginis*. The method is based on ideal free distribution and answers two questions: What is the effect of *Eurosta* oviposition behavior on conspecifics? and How does *Eurosta* respond to varying *Solidago* (host plant) density? Results of the analysis suggest that adult females avoid ovipositing in areas in which other flies have oviposited. Analysis of the effect of host plant density on the growth of fly populations shows a minimal but negative effect. The effect of spatial scale at which data is collected can be critical for this analysis. The entire procedure was repeated for five scales of measurement (1,4,9,16,25 m^2) and results were similar for each scale.

Gap Structure in a Mature Till Plain Forest. JEFFREY S. WARD AND GEORGE R. PARKER, Purdue University, West Lafayette, Indiana 47907.——Canopy type was determined on a five-meter grid for a 8.0 ha study area in the Davis-Purdue Research Forest. At each point the canopy was described as: 1) Primary canopy—the top of the canopy was at least twenty meters above ground, 2) Secondary canopy—the top of the canopy was between five and twenty meters, 3) Gap—top of the canopy was less than five meters. Woody vegetation between two and ten cm dbh were inventoried on a ten-meter grid. Sixty-two percent of the stand had primary canopy, thirty percent had secondary canopy and eight percent of the stand was in gaps. Gap sizes ranged from 25 m^2 to 375 m^2 with a mean of 52 m^2; gap size distribution was lognormal. Using Clark-Evan's nearest neighbor index gaps were found to be randomly dispersed in the study area. Relationships between vegetation and gap sizes are discussed.

Effects of Prescribed Burning on Woody and Herbaceous Vegetation in Black Oak Sand Savannas at Hoosier Prairie Nature Preserve, Lake County, Indiana

John A. Bacone and Thomas W. Post
Indiana Department of Natural Resources
605B State Office Building
Indianapolis, Indiana 46204

Introduction

Black oak sand savannas were common components of the Indiana Presettlement landscape. Betz (3) estimates that the total acreage of savanna and associated sand prairie in Indiana before settlement was 647,000 hectares. Homoya et al. (5), using data from Potzger et al. (9) estimates 514,000 hectares. The United States Public Land Survey notes of 1835 (11) describe areas where savannas are known to exist today as "barrens", that is areas of "open" timber, scattered with "scrubs" for undergrowth. Characteristic trees in these "barrens", according to the survey, were black oaks (*Quercus velutina*) and white oaks (*Quercus alba*). Distances between witness trees were often fifty feet or more. Bacone and Campbell (2) determined that "barrens" as described above are what are referred to as savannas today. They described black oak sand savannas as occurring on sandy soil with a ground cover composed primarily of dry sand prairie species. Maintenance of these communities, both here in Indiana (2) and in other states such as Ohio (8), Illinois (7), Wisconsin (4) and Missouri (6), is attributed primarily to fire.

Today remnants of these savanna communities can still be located in Lake, Newton, Jasper, Porter, Pulaski and Starke Counties. However, most areas have been degraded due to various disturbances such as grazing and/or altered fire regimes.

Hoosier Prairie Nature Preserve is a 135 hectare area owned by the Indiana Department of Natural Resources, and managed by the Division of Nature Preserves. The preserve is a complex of sand prairie, black oak sand savanna, sedge meadow and marsh natural communities, located in the Chicago Lake Plain Section of the Northwestern Morainal Natural Region (5).

The black oak sand savannas at Hoosier Prairie occur on the higher areas, on Brems and Plainfield fine sand. Characteristic woody species include black oak, white oak, sumac (*Rhus copallina, R. glabra*) sweetfern (*Comptonia peregrina*), and late low blueberry (*Vaccinium vacillans*). Typical herbaceous species include: little bluestem (*Andropogon scoparius*), pennsylvania sedge (*Carex pennsylvanica*), tall coreopsis (*Coreopsis tripteris*), woodland sunflower (*Helianthus divaricatus*), and bracken fern (*Pteridium aquilinum latiusculum*).

Rare vascular flora associated with the remnant savannas at Hoosier Prairie Nature Preserve include: pink corydalis (*Corydalis sempervirens*), northern cranesbill (*Geranium bicknellii*), sweet fern (*Comptonia peregrina*), and bog clubmoss (*Lycopodium inundatum*).

Due to the increasing problem of woody species invasion by oaks, willows (*Salix* spp.), aspen (*Populus tremuloides*), sumacs, and other species, prescribed burning is being used as a means of maintaining savanna communities. Since its acquisition in 1977, portions of Hoosier Prairie have been burned every year. Depending on weather conditions, burns occur either in spring or fall. This paper will describe the effects of prescribed burning on woody and herbaceous vegetation at Hoosier Prairie Nature Preserve.

Nomenclature follows Swink and Wilhelm (10).

Methods

Two 10m × 10m plots were established in savanna areas of Hoosier Prairie prior to any controlled burning of the area. Each 10m × 10m plot was subdivided into twenty-five 2m × 2m plots. In each of these smaller plots, all woody stems at subcanopy height or higher (one meter) for each species were tallied. Within each of these smaller plots a $0.67m^2$ circular hoop was randomly thrown to determine herbaceous species presence. All plots were sampled yearly (during midsummer) regardless of whether or not the area had received a controlled burn.

The purpose of the plots was to record and detect changes to the vegetation by the prescribed burning treatment. As such, the 10m × 10m plots were not located randomly but specifically placed within savanna communities which were randomly selected. Plot #1 (north savanna) was located in a relatively uniform, level area. In this plot, sumac was frequent in the understory. In contrast, part of plot #2 (south savanna) was on a slight slope, where aspen was frequent. Moisture conditions were slightly drier in plot #1 than in plot #2.

Results and Discussion

Plot #1. The area containing this block has been burned four times in the last eight years. Three of the burns were conducted in the spring and one was conducted in the fall. This plot was originally sampled following the first prescribed burn. No pre-burn data was available. The number of woody stems increased after a single burn but decreased after two consecutive burns (Table 1). The effects of burning on other woody species found in this plot are as follows: smooth sumac (*Rhus glabra*) has been able to resprout and maintain its original frequency, while willow (*Salix humilis*) and black oak sprouting has declined. The one clump of wild black cherry (*Prunus serotina*) has increased sprouting somewhat in the plot.

TABLE 1. Results of Prescribed Burning at Hoosier Prairie - North Savanna

	*1978	1979	1980	*1981	*1982	1983	*1984	1985
Woody								
Total # Stems	no sample	158	no sample	245	156	161	217	243
# stems/plot		6.32		9.8	6.24	6.44	9.08	9.72
Herbaceous								
Total #		271	no sample	343	363	319	336	342
#ssp/plot		10.84		13.8	14.5	12.8	13.4	13.68
#ssp		38		40	49	38	40	38

* denotes prescribed burn between growing seasons (fall or spring)

The herbaceous flora of plot #1 showed an increase in the number of species/plot and total number of species in the sample after a one and two year burn cycle. The numbers then dropped slightly and maintained themselves after the initial upsurge in numbers.

Plot #2. This area has been burned five times in the last eight years. Three of the burns were conducted in the spring. The first sampling took place prior to any prescribed burning, and this plot had probably not been burned for at least five years prior to sampling. After the initial burn, both total number of woody stems and woody stems/plot increased dramatically (Table 2). After a second successive burn, the number of woody stems dropped and continued to drop through a two year no burn cycle. Then, following burning, the number of stems increased again. In contrast to Plot #1, sprouting increased following two consecutive burns. This increase was due primarily to willow sprouting. Perhaps the willows were stimulated by the fact that the burn took place in very late spring, after leafout had been initiated.

TABLE 2. Results of Prescribed Burning at Hoosier Prairie - South Savanna

	1978	*1979	*1980	1981	1982	*1983	*1984	*1985
Woody								
Total # Stems	220	789	526	384	344	698	795	552
# stems/plot	8.8	31.5	21	15.36	13.84	28	31.8	22.08
Herbaceous								
Total #	160	287	287	246	307	407	357	344
#ssp/plot	6.4	11.5	11.5	9.8	12.2	16.3	14.3	13.76
#ssp	28	54	48	46	49	46	51	55

* denotes prescribed burn between growing seasons (fall or spring)

For specific woody species this pattern of burning has maintained black chokeberry (*Pyrus melanocarpa*), stimulated an initial increase in trembling aspen (*Populus tremuloides*) but eventually reduced it to pre-burn levels, reduced black oak sprouting and stimulated both prairie willow (*Salix humilis*) and other willows (*Salix* sp.)

Burning in general has increased both the number of herbaceous species/plot and the total number of species observed. However, a slight downward trend was observed after the last two prescribed burns.

Overall trends regarding herbaceous species in both of these plots show quantitative increases for *Aster azureus*, *Comandra richardsiana*, *Helianthus mollis*, *Potentilla simplex*, *Rubus flagellaris*, *R. hispidus*, and *Solidago juncea*. Herbaceous species showing little or no change include: *Aster umbellatus*, *Carex pensylvanica*, *Comptonia peregrina*, *Coreopsis tripteris*, *Euphorbia corollata*, *Fragaria virginiana*, *Parthenium integrifolium*, *Pteridium aquilinum*, *Sorghastrum nutans*, *Spirea tomentosa* and *Vaccinium vaccilans*. Species showing a decrease include *Arenaria lateriflora*, *Baptisia leucantha* and *Gaylussacia baccata*.

After prescribed burning was begun at the preserve, two plants not noted before were observed as occurring on the prairie. These were *Geranium bicknellii* and *Corydalis sempervirens*. This is consistent with Swink and Wilhelm's (10) comment that both plants occur in sandy soils after a fire. These plants are both listed as endangered in Indiana (1).

Summary

Woody and herbaceous vegetation are being monitored in black oak sand savanna communities at Hoosier Prairie to determine effects of prescribed burning. Eight years of data showed that occasional burning increased the number of woody stems that are resprouting. Burns of at least two years in succession appear to be necessary to cause a decline in the sprouting of most woody species.

Periodic burning in general (whether frequent or occasional) appears to have a positive effect on herbaceous vegetation as measured by relative frequency (species/plot) and overall number of species observed.

It is too early to speculate on the long term effects of burning on the woody understory in these savannas, but burning appears to be benefiting the herbaceous vegetation.

Acknowledgments

The authors would like to thank the secretary of the Division of Nature Preserves, Jerrie L. Worthy, for typing this manuscript. We would also like to thank Ron Campbell, Irene Herlocker, Ken Klick, Jim Keith, and Gerry Wilhelm, who assisted with plot sampling.

Literature Cited

1. Aldrich, J.R., J.A. Bacone, and M.A. Homoya. 1986. List of extirpated, endangered, threatened, and rare vascular plants in Indiana: an update. Proceedings Indiana Academy of Science. In press.
2. Bacone, J.A. and R.K. Campbell. 1983. Presettlement vegetation of Lake County, Indiana. *In* Proceedings of the Seventh North American Prairie Conference, August 4-6, 1980. Southwest Missouri State University, Springfield, Missouri. 321 p.
3. Betz, R.F. The prairies of Indiana. 1978. *In* Proceedings of the Fifth Midwest Prairie Conference. Iowa State University, Ames, Iowa. 230 p.
4. Curtis, J.C. 1959. The vegetation of Wisconsin. The University of Wisconsin Press, Madison, Wisconsin. 656 p.
5. Homoya, M.A., D.B. Abrell, J.R. Aldrich and T.W. Post. 1985. The natural regions of Indiana. Proceedings Indiana Academy of Science. In press.
6. Iffrig, G. and P. Nelson. 1983. Savannah stewardship in Missouri state parks. Missouri Prairie Journal, Vol. 5, No. 1-2.
7. Madany, M.H. 1981. A floristic survey of savannas in Illinois. *in* Proceedings of the Sixth North American Prairie Conference. August 12-17, 1978. Ohio State University, Columbus, Ohio. 278 p.
8. Moseley, E.L. 1928. Flora of the oak openings west of Toledo. Proceedings of the Ohio Academy of Science. Vol. 8, Part 3, Special Paper #20.
9. Potzger, J.E., M.E. Potzger and J. McCormick. 1956. The forest primeval of Indiana as recorded in the original U.S. land surveys and an evaluation of previous interpretations of Indiana vegetation. Butler Univ. Bot. Stud. 13: 95-111.
10. Swink, F. and G. Wilhelm. 1979. Plants of the Chicago Region. The Morton Arboretum, Lisle, IL. 922 p.
11. United State Public Land Survey. 1835. Field notes for townships twenty-nine, thirty, and thirty-one north and east of the 2nd principal meridian. Indiana State Archives, Indiana State Library, Indianapolis, Indiana.

Thirty Years of Growth Records in Donaldson's Woods

JAMES D. BARTON
Newfane, Vermont 05345
AND
DAMIAN V. SCHMELZ
Saint Meinrad College
St. Meinrad, Indiana 47577

Introduction

Donaldson's Woods, now dedicated as a Nature Preserve, is an 80-acre remnant of original mixed woods forest (3) in Spring Mill State Park, Lawrence County, Indiana. During the summer of 1984 the third 10-year study was made of 19.6 acres of all trees 4-in. d.b.h. and over as measured by diameter tape. In 1954 (1) a 37 × 18 ft. two dimensional map was constructed showing the position, diameter and basal area of each tree. Data on each tree in 1964 (2) and 1974 (4) were recorded directly on the 52 map sections (each 31 × 67 in.) in the field; trees new to the lowest size-class were added to the map, and trees that had died were deleted.

Methods

In preparation for the latest study the first author entered all previous data on Donaldson's Woods onto computer, which generated 11 × 17 in. map sections and comprehensive field data sheets. These were used in the field to record 1984 data. Tree-by-tree comparison on new and old map sections corrected some inaccuracies in the data of the previous studies. George Parker, Purdue University, Paul MacMillan, Hanover College and Mark Kurzendoerfer, Mater Dei High School, Evansville, assisted in the field.

For each 10-year study density and basal area were calculated for each species and each 4-inch size-class. Relative density and relative basal area for each species were averaged to give an importance value. Analysis of these attributes reveals changes and suggests trends in composition, distribution and dominance.

Data are now being converted to metric units for future analyses. Maps, data and computer program will be housed with both authors for future studies.

Lowest-Size-Class

The composition of an undisturbed old growth forest and species dominance are determined mainly throughout the higher size-classes. Significant changes can be detected not only by the rate of growth and survival among the larger trees but also by the number of accessions and deaths in the lowest size-class (4.0-7.9 dbh). These data (Table 1) show that the total number of trees has declined through each decade, by 37% over the 30 years from 1118 to 704. The number of new trees increaed from 145 to 195 (34%); however, the number dying also increased from 130 to 246 (89%). Sugar maple[1] has continued to be the most prolific; nearly half of all trees in this size-class are this species. Through every decade it has shown more accessions than deaths. Second in numbers, beech decreased through each decade, by 48% over the 30 years from 374 to 196. White and green ashes rank a distant third. The pattern observed previously continued for the oaks and the hickories: poor representation, few accessions in the first 20 year and none at all in the last 10 years, high mortality.

Mortality

Much of the mortality among the higher size-classes was due to windthrow, but also there were many trees standing dead from causes unknown. Shading and competi-

TABLE 1. Total number, accessions and deaths of trees in the six-inch size-class, 1954-84.

Species	Total				New			Died		
Qa	79	55	24	7	4	1	0	21	27	20
Fg	374	315	255	196	23	20	30	33	26	50
As	347	367	329	332	81	73	116	11	45	76
Co/Cl	41	35	19	6	1	2	0	7	16	11
Qr	6	2	3	0	0	1	0	1	0	3
Ns	39	28	25	20	2	4	5	10	4	13
Ar	63	57	42	34	1	4	7	8	7	8
Cg	43	32	24	4	5	1	0	15	8	19
Fa/Fp	55	58	56	50	13	12	17	8	10	26
Qv	0	0	0	0	0	0	0	0	0	0
Lt	4	3	0	3	0	0	3	0	1	0
Ov	30	29	26	31	3	6	9	4	7	8
Cc/Ct	5	6	2	1	1	0	0	0	4	1
Cf	20	23	14	13	5	2	5	8	10	8
Others	12	9	6	7	0	2	3	4	4	3
Total	1118	1019	825	704	145	128	195	130	169	246
Per Acre	57.0	52.0	42.1	35.9	7.40	6.53	9.95	6.63	8.62	12.6

tion undoubtedly were responsible for the very high mortality in the lowest size-classes. The bridle trail of previous decades has been removed and is no longer a factor. Whatever mortality might be expected in a stand such as this, the number of deaths continued to increase in nearly every size-class (Table 2). Almost twice as many trees died during the third decade (413) as during the first (219), and the basal area sum lost during the third decade (325.1) was 81% more than that lost during the first decade (179.8). Of all deaths (413) in the last 10 years 60% (246) were in the 6-in. size-class, and more than half (126) of those were beech/maple. However, the 41 trees in the 22-in. class and larger that died in the last 10 years were oaks or hickories. The basal area loss by the oaks and hickories was 79% (258.3) of the total lost (325.1), and more than one third (133.7) was from white oak.

TABLE 2. Number of trees and their actual basal area sums lost by death for all size-classes of white oak, red and black oaks, all hickories, beech and maple, and all other species combined.

	Qa						Qr, Qv					
	Number			B.A.			Number			B.A.		
Size Class	1964	1974	1984	1964	1974	1984	1964	1974	1984	1964	1974	1984
6	21	27	20	4.12	5.30	3.93	1	0	3	0.20	0	0.59
10	8	8	21	4.31	4.36	11.5	1	2	3	0.54	1.09	1.64
14	8	8	8	8.55	8.55	8.55	3	2	7	3.21	2.14	7.48
18	3	3	5	5.30	5.30	8.84	3	0	8	5.30	0	14.1
22	1	8	4	2.64	21.1	10.6	1	2	4	2.64	5.28	10.6
26	2	3	7	7.37	11.1	25.8	3	1	6	11.1	3.69	22.1
30	4	4	8	19.6	19.6	39.3	0	0	1	0	0	4.91
34+	5	7	4	31.5	44.1	25.2	0	0	0	0	0	0
Total	52	68	77	83.4	119.4	133.7	12	7	32	23.0	12.2	61.4
Per Acre	2.65	3.47	3.88	4.26	6.09	6.82	0.61	0.36	1.63	1.17	0.62	3.13

TABLE 2.—Continued

	Co, Cl, Cg, Cc, Ct						Fg, As					
	Number			B.A.			Number			B.A.		
Size Class	1964	1974	1984	1964	1974	1984	1964	1974	1984	1964	1974	1984
6	22	28	31	4.32	5.50	6.09	44	71	126	8.64	13.9	24.7
10	5	8	12	2.72	4.36	6.54	6	8	18	3.27	4.36	9.82
14	4	2	12	4.28	2.14	12.8	0	3	2	0	3.21	2.14
18	1	2	8	1.77	3.53	14.1	3	2	0	5.30	3.53	0
22	3	3	2	7.92	7.92	5.28	0	0	0	0	0	0
26	3	2	5	11.1	7.37	18.4	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
34+	0	0	0	0	0	0	0	0	0	0	0	0
Total	38	45	70	32.1	30.8	63.2	53	84	149	17.2	25.0	36.6
Per Acre	1.94	2.30	3.57	1.64	1.57	3.22	2.70	4.29	7.60	0.88	1.28	1.87

TABLE 2.—Continued

	Others						Total					
	Number			B.A.			Number			B.A.		
Size Class	1964	1974	1984	1964	1974	1984	1964	1974	1984	1964	1974	1984
6	42	43	66	8.24	8.44	13.0	130	169	246	25.5	33.2	48.3
10	16	5	15	8.73	2.73	8.18	36	31	69	19.6	16.9	37.6
14	5	4	5	5.34	4.28	5.34	20	19	34	21.4	20.3	36.4
18	1	1	2	1.77	1.77	3.53	11	8	23	19.4	14.1	40.6
22	0	1	0	0	2.64	0	5	14	10	13.2	37.0	26.4
26	0	0	0	0	0	0	8	6	18	29.5	22.1	66.4
30	0	1	0	0	4.91	0	4	5	9	19.3	24.5	44.2
34+	0	0	0	0	0	0	5	7	4	31.5	44.1	25.2
Total	64	55	88	24.1	24.8	30.0	219	259	413	179.8	212.3	325.1
Per Acre	3.27	2.81	4.49	1.23	1.27	1.53	11.2	13.2	21.1	9.17	10.8	16.6

Growth and Change

Stand density decreased through each decade, by 15% during the 30 years from 119.5 to 101.9 (Table 3). From 1954 to 1964 11.2 trees per acre died (Table 2), but only

TABLE 3. Density and basal area per acre by size classes for all species combined, 1954-84.

Size Class	Density/Acre				Basal Area/Acre			
	1954	1964	1974	1984	1954	1964	1974	1984
6	57.0	52.0	42.1	35.9	11.2	10.2	8.26	7.05
10	20.8	23.1	24.6	24.4	11.3	12.6	13.4	13.3
14	11.4	12.1	11.3	12.0	12.2	13.0	12.1	12.9
18	11.2	9.59	9.08	8.16	19.8	16.9	16.0	14.4
22	7.91	8.32	7.55	6.79	20.9	22.0	19.9	17.9
26	5.87	6.28	6.53	6.22	21.6	23.1	24.1	23.0
30	3.27	3.78	4.18	4.85	16.0	18.5	20.5	23.8
34+	1.94	2.04	2.45	3.52	12.3	12.9	15.4	22.2
Total	119.5	117.2	107.9	101.9	125.3	129.2	129.7	134.6

7.4 trees per acre grew into the 6-in. size-class (Table 1). During 1964-74 13.2 trees were lost; 6.5 were new. From 1974 to 1984 21.1 trees were lost; 9.9 were new. Although mortality increased for all size-classes (Table 2), density has decreased over the 30 years only in size-classes 6, 18 and 22. Growth of surviving trees moved a larger number from these into the next higher classes. Average stem diameter increased from 11.5 in. (1954) to 11.9 (1964) to 12.4 in. (1974) to 13.4 in. (1984). Basal area per acre increased through each decade, by 7.4% over the 30 years from 125.3 to 134.6. Subtracting out the basal area of those trees that died during each decade (Table 2), the survivors added 13.1 square feet of basal area per acre in the first decade, 11.3 during the second and 21.5 during the third.

White oak continues to be the single most important (V_3) species in the woods, but it continues to decline steadily in all attributes (Table 4). It now ranks third in density,

TABLE 4. Comparison of species attributes 1954-84 and net gain (+) or loss (−) of density and basal area.

	Density per Acre (D_2)				Relative Density (D_3)			
Species	1954	1964	1974	1984	1954	1964	1974	1984
Qa	27.1	24.6	20.9	17.8	22.7	21.0	19.4	17.5
Fg	27.2	26.4	24.8	24.8	22.8	22.5	23.0	24.3
As	22.9	27.0	27.6	30.6	19.2	23.0	25.6	30.0
Co/Cl	8.11	7.50	6.33	4.69	6.79	6.40	5.87	4.60
Qr	4.74	4.23	4.08	2.81	3.97	3.61	3.78	2.76
Ns	4.95	4.29	3.72	3.27	4.14	3.66	3.45	3.21
Ar	4.95	4.54	4.03	3.78	4.14	3.87	3.73	3.71
Cg	4.90	4.18	3.47	1.84	4.10	3.57	3.22	1.81
Fa/Fp	4.29	4.44	4.29	4.03	3.59	3.79	3.98	3.95
Qv	3.38	3.32	3.06	2.70	2.83	2.83	2.84	2.65
Lt	1.94	1.89	1.73	1.89	1.54	1.61	1.60	1.85
Ov	1.53	1.48	1.33	1.58	1.28	1.26	1.23	1.55
Cc/Ct	1.48	1.38	1.07	0.82	1.24	1.18	0.99	0.80
Cf	1.02	1.17	0.71	0.66	0.85	1.00	0.66	0.65
Others	0.97	0.82	0.77	0.66	0.81	0.70	0.71	0.65
Totals	119.5	117.2	107.9	101.9				

TABLE 4.—Continued

	Basal Area per Acre (B_2)				Relative Basal Area (B_3)			
Species	1954	1964	1974	1984	1954	1964	1974	1984
Qa	62.0	61.2	59.2	59.4	49.5	47.4	45.6	44.1
Fg	10.9	11.9	13.1	16.2	8.70	9.21	10.1	12.0
As	6.88	9.08	10.5	13.2	5.49	7.03	8.08	9.82
Co/Cl	10.3	10.1	9.44	8.29	8.22	7.82	7.28	6.16
Qr	8.30	8.45	9.24	8.32	6.62	6.54	7.12	6.18
Ns	3.13	2.93	2.67	2.48	2.50	2.27	2.06	1.84
Ar	1.90	1.81	1.80	1.81	1.52	1.40	1.39	1.35
Cg	3.45	3.28	3.12	2.51	2.75	2.54	2.40	1.87
Fa/Fp	2.53	2.82	2.90	3.21	2.02	2.18	2.23	2.39
Qv	7.86	8.99	9.37	9.77	6.27	6.69	7.22	7.26
Lt	5.44	5.76	5.77	6.89	4.34	4.46	4.45	5.12
Ov	0.30	0.29	0.26	0.31	0.24	0.22	0.20	0.23
Cc/Ct	1.67	1.76	1.64	1.46	1.33	1.36	1.26	1.09
Cf	0.20	0.23	0.14	0.13	0.16	0.18	0.11	0.10
Others	0.55	0.56	0.61	0.59	0.44	0.43	0.47	0.44
Totals	125.3	129.2	129.7	134.6				

TABLE 4.—Continued

	Importance (V_3)				% Change 1954-84	
Species	1954	1964	1974	1984	D_2	B_2
Qa	36.1	34.2	32.5	30.8	−34.3	− 4.19
Fg	15.8	15.9	16.6	18.2	− 8.8	+48.6
As	12.4	15.0	16.8	19.9	+33.6	+91.9
Co/Cl	7.50	7.11	6.56	5.38	−42.2	−19.5
Qr	5.30	5.08	5.45	4.47	−40.7	+ 0.24
Ns	3.32	2.96	2.76	2.52	−33.9	−20.8
Ar	2.83	2.64	2.56	2.53	−23.6	− 4.74
Cg	3.42	3.06	2.81	1.84	−62.4	−27.2
Fa/Fp	2.80	2.98	3.10	3.17	− 6.07	+26.9
Qv	4.55	4.90	5.03	4.96	−20.1	+24.3
Lt	2.94	3.04	3.02	3.48	− 2.58	+26.6
Ov	0.76	0.74	0.72	0.89	+ 3.27	+ 3.33
Cc/Ct	1.28	1.27	1.12	0.94	−44.6	−12.6
Cf	0.50	0.59	0.38	0.38	−35.3	−35.0
Others	0.62	0.56	0.59	0.54	−32.0	+ 7.27
Totals					−14.3	+ 7.42

but it still dominates by basal area. Growth has been good, almost offsetting the heavy loss of large stems (Table 2).

Sugar maple is second and beech third in importance, and their gains have been steady through the 30 years. Sugar maple has been the most abundant species for the last 20 years; it ranks third, behind beech, in basal area at this time.

Other species which impact the woods and impress the visitor with their large stems include red and black oaks, the several hickories and tulip. All of these are declining in number. Black oak and tulip have gained slightly in basal area; the rest have decreased. Mortality is high; new 6-in. trees are few to none.

Trend

The kind of changes recognized in 1964 and seen again in 1974 were evident once more in 1984. Beech and maple have lost considerably more trees than all the oaks and hickories combined, but the oaks and hickories lost six times as much basal area. Of the trees 20-in. and larger which have died during the 30 years 95% were among the oaks and hickories. In the lowest size-class only sugar maple more than replaced deaths by new trees. Beech is abundant, and only a few other mesic species are reproducing and growing into the lowest size class. The trend seems to be from an oak-hickory-tulip dominant stand to one which is more of mixed mesophytic nature with beech and maple dominating.

Literature Cited

1. Lindsey, A.A., J.D. Barton, Jr., and S.R. Miles. 1958. Field efficiencies of forest sampling methods. Ecology 39:428-444.
2. Lindsey, A.A. and D.V. Schmelz. 1965. Comparison on Donaldson's Woods in 1964 and its 1954 map of 20 acres. Proc. Indiana Acad. Sci. 74:169-177.
3. ______. 1970. The forest types of Indiana and a new method of classifying midwestern hardwood forests. Proc. Indiana Acad. Sci. 79:198-204.
4. Schmelz, D.V., J.D. Barton, and A.A. Lindsey. 1975. Donaldson's Woods: Two Decades of Change. Proc. Indiana Acad. Sci. 84:234-243.

Note

[1] Ar *Acer rubrum*, As *Acer saccharum*, Cc *Carya cordiformis*, Cg *Carya glabra*, Cl *Carya laciniosa*, Co *Carya ovata*, Ct *Carya tomentosa*, Cf *Cornus Florida*, Fg *Fagus grandifolia*, Fa *Fraxinus americana*, Fp *Fraxinus pennsylvanica*, Lt *Liriodendron tulipfera*, Ns *Nyssa sylvatica*, Ov *Ostrya virginiana*, Qa *Quercus alba*, Qr *Quercus rubra*, Qv *Quercus velutina*, and others are *Carpinus caroliniana*, *Celtis occidentalis*, *Juglans nigra*, *Morus rubra*, *Tilia americana*, *Ulmus americana*, *Ulmus rubra*, *Ulmus thomasi*.

Pesticide Use in No-till Row-crop Fields Relative to Wildlife

John S. Castrale
Indiana Division of Fish and Wildlife
Mitchell, Indiana 47446

Introduction

Increased cover and food resources for wildlife result from the use of conservation tillage compared to conventional tillage practices (5, 10, 24, 25). A potential environmental drawback, however, is the possibility of increased exposure of wildlife to chemical pesticides and fertilizers. The primary purpose of this study was to determine how pesticide use differed between no-till and conventional planting practices in row-crop cultivation. Additionally, attempts were made to explore the impacts to wildlife of pesticide use under these tillage systems. Lastly, the relative merits of enhanced habitat conditions from no-till versus reduced pesticide use from conventional tillage were assessed.

Although a number of tillage practices qualify as conservation tillage, I was concerned with no-till or zero tillage, the most extreme form of reduced tillage practices. In no-till, herbicides substitute totally for mechanical practices in preparing a seedbed and controlling weeds. A contact herbicide kills all green vegetation at the time of planting and the crop is seeded directly into a narrow slot or drilled into the existing residue. Conventional tillage operations consist of mechanically preparing a seedbed by plowing, discing, and harrowing. Subsequent weed control depends on a combination of herbicides and mechanical treatment.

The deer mouse (*Peromyscus maniculatus*) was chosen as the subject for study of the impacts of pesticide use because this species was common under all field situations examined. Although birds may be more sensitive to the harmful effects of chemicals, nesting bird densities in row-crop fields are very low (5). Thus, it is difficult and time-consuming to find nests, and the residency status and amount of time that an encountered bird spends in a particular field are not known. Therefore, the extent of exposure to applied chemicals is unknown. Shrews (Soricidae) may be more appropriate mammals to study due to their higher trophic level. However, they were rarely encountered. Deer mice are acceptable subjects because they are year-round residents in row-crop fields, and their numbers are not greatly influenced by tillage practices and the habitat conditions that result (10). Because their diet is composed of a wide variety of invertebrates and plant seeds, deer mice may be exposed to agricultural chemicals through several pathways. Thus, the deer mouse may serve as a model of omnivores.

Methods

Pesticide Use

Information on pesticide use was obtained for 56 corn and soybean fields studied during 1983-1985 in Scott County, southeastern Indiana. All farms were privately operated and were selected on the basis of past and proposed planting and tillage conditions. The Scott County office of the Soil Conservation Service obtained pesticide application rates directly from farm operators. Toxicity levels of pesticides (Table 1) were obtained from published sources (8, 20).

Short-term Impacts of Planting

To explore the short-term impacts of chemical use and spring tillage practices, population densities and turnover rates of small mammals were measured using live trapping and marking methods. Deer mice were studied in 6 Lawrence County cornfields during 1984. All were private farms operated by local landowners and selected on the basis of

TABLE 1. Pesticides used on Scott County study fields.

Chemical name	Trade name	Reported acute oral toxicity, LD_{50} (mg/kg)
Herbicide		
Acifluorfen	Blazer	1,300
Alachlor	Lasso	1,800
Alachlor; glyphosate	Bronco	1,800; 4,300
Atrazine	AAtrex	3,080
Atrazine; metolachlor	Bicep	3,080; 2,780
Bentazon	Basagran	1,100
Butylate	Sutan +	4,659
2,4-D	2,4-D	300*-1,200
EPTC	Eradicane	1,630
Fluazifop-butyl	Fusilade	1,272
Glyphosate	Roundup	4,300
Linuron	Lorox	1,500
Metolachlor	Dual	2,780
Metribuzin	Lexone	1,930
Paraquat	Paraquat	150*
Trifluralin	Treflan	3,700
Insecticide		
Carbofuran	Furadan	11**
Isofenphos	Amaze	28**
Terbufos	Counter	4**

* Moderately toxic.

** Highly toxic.

current and proposed cultivation. Fields selected included one that had been planted to corn previously but was to be diverted from production and thus served as a control. A variety of annual and perennial forbs and grasses was present. One field was virtually a pure stand of sweet clover (*Meliotus* spp.) with a few patches of thistle (*Cirsium* spp.). This field was conventionally tilled and planted with corn. Four fields were planted to corn using no-till methods. Corn (field 3 in Table 2) and soybean (field 4) residue predominated in 2 no-till fields, while fields 5 and 6 had been idled the previous year and were dominated by sweet clover. A rodenticide (zinc phosphide) was intended for use on two of the no-till fields but delayed planting conditions and excessive vegetation growth precluded the use of this chemical. Planting information and pesticide use is detailed in Table 2.

Mammals were captured in aluminum live traps (8 × 9 × 23 cm) arranged in a 6 × 8 grid with 15-m spacing. Sunflower seeds were used for bait and traps checked once daily over a 2-week period prior to the planned planting date and for 3-5 weeks after planting. Trapping intensity for individual fields is given in Table 2.

Trapping began 19 April and pre-planting trapping was completed by 2 May (Table 2). One field was planted earlier than expected so trapping was terminated prematurely. Intervals between trapping periods varied among fields due to differences in planting dates.

Captured mammals were individually marked by clipping toes and immediately released. The CAPTURE program (26) was used to calculate estimates of population density. The open model (M_0) was used in estimation although other models were selected as more appropriate in some cases. The open model was used throughout because this model was most appropriate in a majority of cases, a consistently used model was desirable for comparisons between fields and treatments, and some of the models selected did not provide population estimates. Animal densities were calculated from the population

TABLE 2. Planting information and trapping results for 6 Lawrence County cornfields studied during 1984. Data from pre- and post-planting trapping periods are separated by a slash.

	Field					
	1	2	3	4	5	6
Tillage type[a]	ID	CT	NT	NT	NT	NT
Date						
Tillage	—	19 MAY	—	—	—	—
Pesticide application	—	31 MAY	2 JUN	2 MAY	25 MAY	6 JUN
Planting	—	31 MAY	1 JUN	1 MAY	24 MAY	6 JUN
Application rates of pesticides (kg/ha)						
Paraquat	—	—	0.6	0.4	0.3	0.3
Atrazine	—	1.8	1.8	2.7	1.8	1.8
Metolachlor	—	—	1.1	1.1	2.2	2.2
EPTC	—	9.0	—	—	—	—
Carbofuran	—	1.7	1.5	1.3	1.7	1.7
Nights trapped	11/15	11/14	11/14	5/23	11/14	11/14
Days between trapping periods	20	34	34	7	34	41
Captures						
Deer mouse	25/29	17/23	6/5	10/50	16/19	26/19
Prairie vole	1/3	57/0	0/0	0/0	0/15	5/2
White-footed mouse	0/0	1/0	0/0	0/0	0/3	0/8
Population density (no./ha)						
Deer mouse	27/29	17/27[b]	16/4	22/54[b]	15/21[b]	29/6[b]
Prairie vole	–[c]/–[c]	96/0[b]	0/0	0/0	0/31[b]	–[c]/–[c]
White-footed mouse	0/0	–[c]/0	0/0	0/0	0/–[c]	0/17
Recapture rates of deer mice (%)	42	6	67	38	25	26

[a] Idled (ID), conventionally tilled (CT), no-till (NT).

[b] Pre- and post-planting densities significantly ($P < 0.05$) different.

[c] Too few individuals captured to estimate density.

estimates by dividing by 1.08 ha, the assumed effective trapped area of each 6 × 8 grid with 15 m spacing of traps.

The assumption of closure may have been violated by using a grid size smaller than recommended and by trapping for extended periods of time. Thus, estimates of population densities may be inflated. However, estimating densities was secondary to capturing and marking individuals to determine relative recovery rates between capture periods. Both numbers of individuals captured and density estimates are presented in Table 2, although density estimates allow better comparisons between trapping periods because they take into account trapping effort and the extent of animal movements.

Results

Pesticide Use

Fourteen herbicides (16 commercial formulations) and 3 insecticides were used on the Scott County corn and soybean fields during this 3-year study (Tables 1, 3). Her-

TABLE 3. Application rates (kg/ha of active ingredient) and frequency of use (in parentheses) of pesticides used on 56 corn and soybean fields in Scott County, Indiana, 1983-1985.

Pesticide	Conventional				No-till			
	Corn (N = 14)		Soybeans (N = 14)		Corn (N = 14)		Soybeans (N = 14)	
Herbicide								
Alachlor[a]	2.66	(8)	2.39	(9)	2.80	(13)	2.61	(9)
Atrazine[b]	1.70	(14)	—	(0)	1.78	(14)	—	(0)
Paraquat	—	(0)	—	(0)	0.48	(14)	0.40	(10)
Linuron	—	(0)	0.65	(6)	—	(0)	0.65	(13)
Metolachlor[b]	2.10	(2)	—	(0)	2.10	(1)	2.24	(4)
Metribuzin	—	(0)	0.35	(3)	—	(0)	0.19	(3)
Trifluralin	—	(0)	1.06	(5)	—	(0)	—	(0)
Glyphosate[a]	—	(0)	—	(0)	—	(0)	1.54	(4)
Butylate	7.47	(3)	—	(0)	—	(0)	—	(0)
Fluazifop-butyl	—	(0)	0.28	(1)	—	(0)	0.28	(1)
EPTC	6.16	(1)	—	(0)	—	(0)	—	(0)
Bentazon	—	(0)	0.56	(1)	—	(0)	—	(0)
Acifluorfen	—	(0)	0.56	(1)	—	(0)	—	(0)
2,4-D	—	(0)	—	(0)	—	(0)	0.63	(1)
Insecticide								
Carbofuran	2.02	(2)	—	(0)	2.13	(6)	—	(0)
Terbufos	1.12	(3)	—	(0)	—	(0)	—	(0)
Isofenphos	1.57	(1)	—	(0)	—	(0)	—	(0)

[a] Sometimes applied as Bronco.
[b] Sometimes applied as Bicep.

bicides were used on all 56 fields while insecticides were applied to only 12 (21%) fields (Table 3). Insecticides were not applied to any soybean fields, while 12 (43%) cornfields ($X^2 = 15.3$, df = 1, $P < 0.001$) were treated with insecticides, primarily for corn rootworms. An equal number of no-till and conventionally tilled cornfields were treated with insecticides.

The number of different herbicides used in each field was consistently 2.0 for conventional cornfields and 3.0 for no-till cornfields. The difference is totally due to the addition of a contact herbicide (paraquat) used with no-till. For soybean fields, a mean of 1.9 herbicides was used on conventionally tilled fields compared to 3.2 for no-till fields. Again the difference is primarily due to the use of a contact herbicide (paraquat, glyphosate) in the no-till fields.

Acute oral toxicities of pesticides were used as a general guide to determine the potential impacts of chemical use on wildlife frequenting row-crop fields. All 3 insecticides are classified as highly toxic to rodents, while herbicides are rated less toxic (Table 1). Reported oral toxicities are low for all herbicides except paraquat and some formulations of 2,4-D.

Of the chemicals considered, only paraquat and glyphosate are unique to no-till situations. Therefore, comparisons of tillage systems should focus primarily on these herbicides. However, the frequency and application rates of other chemicals may be influenced by the choice of tillage system and should also be examined. Application rates of alachlor were 9% greater in no-till soybean fields than conventionally tilled soybeans, but rates of linuron were similar (Table 3). Application rates of atrazine and alachlor were 5% greater in no-till cornfields compared to conventional cornfields.

Short-term Impacts of Planting

Deer mouse population densities during the pre-planting period averaged 21.0

animals/ha with a range of 15-29/ha (Table 2). Densities during the post-planting period averaged 23.5 animals/ha and ranged from 4-54 mice/ha. The idled field showed similar densities during both trapping periods, while the tilled field indicated a significant increase. The increase was most likely an artifact of increased movements of individuals caused by the disruption of home ranges attributable to disturbances from tillage operations. Deer mouse densities in no-till fields declined in 2 fields (although only 1 difference was statistically significant) and increased significantly in 2 fields. Due to the ambiguity of these results, it appears that tillage and spraying treatments or the absence of them have little discernible, direct impacts on deer mouse densities on a short-term basis. If chemical applications and tillage operations were immediately detrimental to deer mice, population densities and recapture rates should have been drastically and consistently lower during the post-planting period.

Although deer mice predominated in most fields studied, other species were important in several fields. A large prairie vole (*Microtus ochrogaster*) population existed in a dense stand of sweet clover, but was decimated when this habitat was converted to bare ground prior to planting. This species colonized one of the no-till fields between trapping periods. A population of white-footed mice (*Peromyscus leucopus*) was also found in moderate densities in a no-till field during the post-planting trapping period.

Recapture rates (proportion of rodents marked during the first trapping period and subsequently recaptured during the second period) were low for all fields including the control field (Table 2). Mean recapture rates were highest for the control field (42%) and lowest for the conventionaly tilled field (6%). No-till fields generally had intermediate values (25-68%) and the overall recapture rate of 31% for no-till fields was not appreciably lower than the control field, considering the differences in the time intervals between trapping periods. Again, recapture rates lend support to the conclusion that tillage is more disruptive than no-till planting over the short term.

Discussion

The ultimate impact of pesticides to farmland wildlife depends upon a complex combination of factors, including type of pesticides, formulation of chemicals, acute and chronic toxicity of chemicals, toxicity of surfactants and carriers, interactions among different pesticides, interactions of chemicals with soil and vegetation, persistence of chemicals, application rate, mode of application, timing of application, and species of wildlife and their behavior. Chemicals can be applied in many different ways: sprayed on foliage, incorporated into the soil, banded below the soil surface, or broadcast on the soil surface. Modes of application pose differing risks to wildlife depending on food habits and feeding behavior of a species.

Rough comparisons of relative toxicities among pesticides may be made by considering reported acute toxicities and application rates used in this study. With this analysis, carbofuran is potentially 60 × more toxic than paraquat in corn plantings. Similar comparisons of paraquat with atrazine and alachlor in corn, show paraquat being potentially more toxic by a fctor of 6 × and 2 ×, respectively. In soybean fields, paraquat may be 7-8 × more toxic than glyphosate. Thus, insecticide use, which was similar in no-till and conventional tillage situations, should be the primary focus of environmental concern. Insecticides, however, were not frequently employed in this study, especially in soybean fields.

Carbofuran, the most commonly used insecticide in this study, has been the subject of numerous studies (12). Detrimental effects in wildlife have been documented in laboratory trials (4, 22, G. Linder, Cornell Univ., unpubl. data) and carbofuran has been shown to be a source of mortality under actual field conditions (2, 3, 14, 15). Because it is commonly used in granular form, carbofuran is readily ingested as grit or mistaken for food by birds and small mammals.

Deer mice collected from some of the fields included in this study were analyzed for herbicide residues and the results have been reported previously (7). Of 4 herbicides included, residues of atrazine, linuron, and alachlor were not detected or the levels found were minor. Liver damage was not noted in deer mice from fields in which these chemicals were used. All 3 pooled samples of deer mice (15 mice from 2 fields) tested for paraquat revealed metabolites presumed to be degradation products of this herbicide. Two of 3 mice from paraquat-treated fields had damaged livers consistent with paraquat effects (24).

Literature on the effects of paraquat in the laboratory is numerous (see 7), but difficult to interpret from a wildlife standpoint at normal field application levels. Bauer (6) found minimal negative impacts of paraquat on northern bobwhite (*Colinus virginianus*) survival, growth, and reproduction at field application rates. Bunck et al. (9) could find no differences in discrimination learning abilities of northern bobwhite fed paraquat. Paraquat, however, has been shown to negatively affect survival and reproduction in prairie voles (G. Linder, unpubl. data), and the growth and survival of young American kestrels (*Falco sparverius*) (19). Paraquat exhibited a high degree of embryotoxic and teratogenic effects on mallard (*Anas platyrhynchos*) eggs (17, 18).

Because most laboratory studies indicate detrimental effects of paraquat, further research at the field level is warranted, and the use of glyphosate as a preferred alternative should be encouraged. Glyphosate has been found to pose little environmental hazard at field application rates (1, 13, 16).

Although this study addresses pesticide use exclusively in the terrestrial environment, off-site aquatic contamination should be considered. Many agricultural chemicals are more toxic to fish and other aquatic life than they are to terrestrial organisms (21). Compared to conventional planting methods, substantially greater amounts of vegetative residues are present after minimum tillage, resulting in reduced movement of soil particles into waterways. This difference would appear to offset any negative impacts of greater application rates of some pesticides used in no-till (11).

Acknowledgments

R.T. Speer assisted in all phases of this study and R.E. Rolley provided statistical assistance. D. Fellows obtained the cooperation of landowners and provided pesticide application rates from farmers. I appreciate the cooperation of the landowners on whose farms I worked. This study was funded by Federal Aid to Wildlife Restoration Project W-26-R and the Indiana Division of Fish and Wildlife.

Summary

Application rates of pesticides were compiled for 56 no-till and conventional corn and soybean fields in Scott County, southeastern Indiana, 1983-1985. The most common of 14 herbicides used were alachlor, atrazine (cornfields), paraquat (no-till fields), and linuron (soybean fields). Three insecticides, primarily carbofuran, were used on 21% of the fields, all cornfields. Reported acute oral toxicities of these chemicals were generally rated low, except for the insecticides, which were classified as highly toxic, and paraquat and some formulations of 2,4-D, which were classified as moderately toxic. Application rates of alachlor were 9% greater in no-till soybean fields than conventionally tilled soybeans, but rates of linuron were similar. Application rates of atrazine and alachlor were 5% greater in no-till cornfields compared to conventional cornfields. Small mammal populations studied by capture trapping methods in Lawrence County indicated that conventional tillage is more disruptive than the short-term effects of no-till planting methods.

Literature Cited

1. Anthony, R.G., and M.L. Morrison. 1985. Influence of glyphosate herbicide on small mammal populations in western Oregon. Northwest Sci. 59:159-168.
2. Balcomb, R. 1983. Secondary poisoning of red-shouldered hawks with carbofuran. J. Wildl. Manage. 47:1129-1132.
3. Bolcomb, R., C.A. Bowen II, D. Wright, and M. Law. 1984. Effects on wildlife of at-planting corn applications of granular carbofuran. J. Wildl. Manage. 48:1353-1359.
4. Balcomb, R., R. Stevens, and C. Bowen II. 1984. Toxicity of 16 granular insecticides to wild-caught songbirds. Bull. Environ. Contam. Toxicol. 33:302-307.
5. Basore, N.S., L. B. Best, and J.B. Wooley, Jr. 1986. Bird nesting in Iowa no-tillage and tilled cropland. J. Wildl. Manage. 50:19-28.
6. Bauer, C.A. 1985. Effects of paraquat on reproduction and growth in northern bobwhite. J. Wildl. Manage. 49:1066-1073.
7. Benson, D., C.D. Baker, B.J. Forsyth, and J.S. Castrale. 1985. Herbicide (alachlor, atrazine, linuron, and paraquat) residues in deer mice inhabiting conventional and minimum tillage row-crop fields. Proc. Indiana Acad. Sci. 94:373-380.
8. Bohmont, B.L. 1983. The new pesticide user's guide. Reston Publishing Co., Inc., Reston, Virginia. 452 pp.
9. Bunck, C.M., T.J. Bunck, and L. Sileo. 1986. Discrimination learning in adult bobwhite quail fed paraquat. Environ. Toxicol. Chem. 5:295-298.
10. Castrale, J.S. 1985. Responses of wildlife to various tillage conditions. Trans. N. Am. Wildl. and Nat. Resour. Conf. 50:142-156.
11. Crosson, P. 1982. Conservation tillage and conventional tillage: a comparative assessment. U.S. Environ. Protection Agency Rep. No. 600/3-82-027. 72 pp.
12. Eisler, R. 1985. Carbofuran hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.3). 36 pp.
13. Evans, D.D., and M.J. Batty. 1986. Effects of high dietary concentrations of glyphosate (Roundup) on a species of bird, marsupial and rodent indigenous to Australia. Environ. Toxicol. Chem. 5:399-401.
14. Flickinger, E.L., K.A. King, W.F. Stout, and M.M. Mohn. 1980. Wildlife hazards from Furadan 3G applications to rice in Texas. J. Wildl. Manage. 44:190-197.
15. Flickinger, E.L., C.A. Mitchell, D.H. White, and E.J. Kolbe. 1986. Bird poisoning from misuse of the carbamate Furadan in a Texas rice field. Wildl. Soc. Bull. 14:59-62.
16. Ghassemi, M., S. Quinlivan, and M. Dellarco. 1982. Environmental effects of new herbicides for vegetation control in forestry. Environ. Int. 7:389-401.
17. Hoffman, D.J., and P.H. Albers. 1984. Evaluation of potential embryotoxicity and teratogenicity of 42 herbicides, insecticides, and petroleum contaminants to mallard eggs. Arch. Environ. Contam. Toxicol. 13:15-27.
18. Hoffman, D.J., and W.C. Eastin, Jr. 1982. Effects of lindane, paraquat, toxaphene, and 2,4,5-trichlorophenoxyacetic acid on mallard embryo development. Arch. Environ. Contam. Toxicol. 11:79-86.
19. Hoffman, D.J., J.C. Franson, O.H. Pattee, and C.M. Bunck. 1985. Survival, growth, and histopathological effects of paraquat ingestion in nestling American kestrels (*Falco sparverius*). Arch. Environ. Contam. Toxicol. 14:495-500.
20. Hudson, R.H., R.K. Tucker, and M.A. Haegele. 1984. Handbook of toxicity of pesticides to wildlife, 2nd ed. U.S. Fish Wildl. Serv. Resour. Publ. 153. 90 pp.
21. Johnson, W.W., and M.T. Finley. 1980. Handbook of acute toxicity of chemicals to fish and aquatic invertebrates. U.S. Fish Wildl. Serv. Resour. Publ. 137. 98 pp.
22. Robel, R.J., R.W. Felthousen, and A.D. Dayton. 1983. Effects of dietary carbofuran

on bobwhite activity patterns. Bull. Environ. Contam. Toxicol. 30:105-109.
23. Smith, P., and D. Heath. 1976. Paraquat. Critical Rev. Toxicol. 4:411-445.
24. Warburton, D.B., and W.D. Klimstra. 1985. Wildlife use of no-till and conventionally tilled corn fields. J. Soil and Water Conser. 39:327-330.
25. Wooley, J.B., L.B. Best, and W.R. Clark. 1985. Impacts of no-till row cropping on upland wildlife. Trans. N. Amer. Wildl. and Nat. Resour. Conf. 50:157-168.
26. White, G.C., K.P. Burnham, D.L. Otis, and D.R. Anderson. 1978. User's guide manual for program CAPTURE. Utah State Univ. Press, Logan. 40 pp.

Avian Surveys along Two River Segments in Southern Indiana

JOHN S. CASTRALE AND STEVE E. BACKS
Indiana Division of Fish and Wildlife
Mitchell, Indiana 47446
AND
DAVID HOWELL
Indiana Division of Fish and Wildlife
Winslow, Indiana 47598

Introduction

Bird communities along rivers and streams are infrequently studied due to their relative inaccessibility. Forested areas along waterways may represent the only significant contiguous woodlands in regions of intensive agriculture (1). These areas provide important breeding habitat and travel corridors for avian species that utilize upland and lowland woodlands (1, 2, 5). In an Iowa study, floodplain woodlands supported higher densities of breeding birds than either upland woodland or herbaceous riparian habitats (1,5). Bird species richness increased with the width of the wooded riparian area.

Riparian woodlands are constantly threatened by destruction and modification due to urbanization, channelization, and clearing for agricultural and industrial uses (2). Only 10-14 million ha of the estimated original 30-40 million ha of riparian habitats remain in the contiguous United States (6).

Our objectives were to document bird species present along two rivers in southern Indiana, determine the relative abundance of birds, and compare the avifauna of two waterways that differ in the amount of surrounding forestland. We know of no other systematic surveys of birds along any river segment in Indiana.

Study Areas and Methods

The 18.5 km segment of Salt Creek was located in Lawrence County and began just east of Guthrie and proceeded south to Oolitic. The put-in on Salt Creek is approximately 4.5 km downstream from the dam of Monroe Reservoir. The survey of the 18.3 km segment of the Patoka River was in Pike County and began just west of state road 257 south of Velpen and flowed northwest to the Pike State Forest. The starting point is over 35 km (aerial distance) from the dam of Patoka Reservoir. Annual flow rates of both river segments are similar (approximately 600 cfs) and are influenced by reservoir practices administered by the U.S. Army Corps of Engineers. Major tree species along Salt Creek and the Patoka River were silver maple (*Acer saccharinum*) and American sycamore (*Platanus occidentalis*). Salt Creek also contained elm (*Ulmus* spp.), boxelder (*Acer negundo*), and basswood (*Tilia americana*). Oaks (*Quercus* spp.), hickories (*Carya* spp.), and river birch (*Betula rubra*) were common along the Patoka River.

Surveys began within 30 minutes of sunrise on days with little wind and no rain. A canoe with an electric motor was used and 2-3 observers were present during each survey, which lasted 4-5 hours depending on the current. The primary author sat in the front of the canoe and counted and recorded all birds seen or heard. The vast majority of birds were detected by sound. No effort was made to estimate densities by determining detectabilities of individual species. Surveys were conducted once annually from 1984-1986 during the first week of June for Salt Creek, while those along the Patoka River were run in mid-June.

The relative amount of woodland adjoining these river segments was estimated from aerial photographs (scale approximately 1:24,000) obtained from the USDA Agricultural Stabilization and Conservation Service and had been taken in 1974 (Patoka River) or

1979 (Salt Creek). For each river segment, 100 random points (out of a possible 1400-1500) were selected for sampling. At each point, the perpendicular distance from the center of the river channel to non-forested habitat on each side was measured. Both distances combined measured the width of the wooded riparian corridor. To determine the relative composition of a 0.4-km corridor along the rivers, 26 points were evaluated at each of the 100 random sampling points. Each point was judged to be either forested or non-forested.

Cluster analyses were performed to determine relationships among the six surveys relative to river segment and year of the survey. Dissimilarities (absolute values of differences and coefficients of determination, $1 - r^2$) were calculated between all 15 combinations of pairs of surveys. Clustering was performed using the Statistical Analysis System software package and single linkage, average linkage, centroid hierarchical, and Ward's minimum variance methods.

Results and Discussion

The Patoka River contained significantly more ($P_5 < 0.05$) woodland (78%) than Salt Creek (38%) within 0.4 km of the stream channel. The median perpendicular width of continuous woodland adjoining each stream segment was 117 m for Salt Creek and 844 m for the Patoka River ($P_5 < 0.05$). The median perpendicular distance from the stream channel to the nearest non-forested habitat was 42 m for Salt Creek and 319 m for the Patoka River ($P_5 < 0.05$). These distance figures actually underestimated the differences of continuous woodland habitat between river systems. In the Patoka River area, woodlands were broken primarily by narrow corridors such as roads and utility right-of-ways. In contrast, riparian woodlands along Salt Creek were bordered by cultivated fields.

A total of 77 avian species was detected on the six surveys (Table 1). Mean species

TABLE 1. Birds (no. indivduals/10km) detected on canoe surveys of Salt Creek (Lawrence County) and Patoka River (Pike County), Indiana, 1984-1986.

	Salt Creek		Patoka River		
Bird species	Mean	Range	Mean	Range	P^a
No. species/survey	53.3	49.0-58.0	52.0	51.0-54.0	NS
Great blue heron (*Ardea herodias*)	0.0		0.5	0.0-1.1	NS
Green-backed heron (*Butorides striatus*)	0.2	0.0-0.5	0.0		NS
Yellow-crowned night-heron (*Nycticorax violaceus*)	0.0		0.9	0.0-2.2	NS
Wood duck (*Aix sponsa*)	42.7	29.7-67.0	11.5	5.5-19.1	NS
Turkey vulture (*Cathartes aura*)	0.7	0.0-1.6	0.5	0.0-1.1	NS
Red-shouldered hawk (*Buteo lineatus*)	0.0		4.0	3.8-4.4	***
Red-tailed hawk (*Buteo jamaicensis*)	1.1	0.0-2.2	0.5	0.0-1.6	NS
Wild turkey (*Meleagris gallopavo*)	0.0		0.2	0.0-0.5	NS
Northern bobwhite (*Colinus virginianus*)	6.3	2.7-8.6	3.1	1.1-5.5	NS
Killdeer (*Charadrius vociferus*)	0.5	0.0-1.1	0.0		NS
Rock dove (*Columba livia*)	1.4	0.5-3.2	0.0		NS

Table 1.—Continued

Bird species	Salt Creek		Patoka River		
	Mean	Range	Mean	Range	P^a
Mourning dove (*Zenaida macroura*)	3.2	3.2	0.7	0.0-2.2	*
Black-billed cuckoo (*Coccyzus erythropthalmus*)	0.2	0.0-0.5	0.2	0.0-0.5	NS
Yellow-billed cuckoo (*Coccyzus americanus*)	1.6	0.0-3.2	7.6	6.0-8.7	**
Great horned owl (*Bubo virginianus*)	0.4	0.0-0.5	0.2	0.0-0.5	NS
Barred owl (*Strix varia*)	1.6	1.1-2.2	0.9	0.0-1.6	NS
Whip-poor-will (*Caprimulgus vociferus*)	0.0		0.2	0.0-0.5	NS
Chimney swift (*Chaetura pelagica*)	1.3	0.0-2.2	2.0	0.5-3.8	NS
Ruby-throated hummingbird (*Archilochus colubris*)	0.0		4.9	4.4-5.5	***
Belted kingfisher (*Ceryle alcyon*)	0.7	0.0-1.6	0.9	0.0-2.2	NS
Red-headed woodpecker (*Melanerpes erythrocephalus*)	0.9	0.5-1.1	2.4	0.5-4.9	NS
Red-bellied woodpecker (*Melanerpes carolinus*)	3.8	1.6-5.9	4.4	3.8-4.9	NS
Downy woodpecker (*Picoides pubescens*)	1.6	0.0-3.2	3.3	1.1-6.0	NS
Hairy woodpecker (*Picoides villosus*)	0.7	0.0-2.2	0.4	0.0-0.5	NS
Northern flicker (*Colaptes auratus*)	3.4	1.6-6.5	1.3	0.5-1.6	NS
Pileated woodpecker (*Dryocopus pileatus*)	2.2	0.5-3.8	5.1	3.3-8.7	NS
Eastern wood-pewee (*Contopus virens*)	18.7	17.3-20.5	17.7	13.1-21.8	NS
Acadian flycatcher (*Empidonax virescens*)	29.7	29.2-30.8	24.0	22.4-26.2	*
Willow flycathcer (*Empidonax traillii*)	0.0		0.4	0.0-0.5	NS
Eastern phoebe (*Sayornis phoebe*)	1.1	0.5-2.2	0.7	0.0-1.6	NS
Great crested flycatcher (*Myiarchus crinitus*)	2.9	2.2-3.2	6.6	4.9-7.6	*
Eastern kingbird (*Tyrannus tyrannus*)	0.7	0.0-1.1	0.5	0.0-1.1	NS
N. rough-winged swallow (*Stelgidopteryx serripennis*)	0.2	0.0-0.5	0.4	0.0-1.1	NS
Bank swallow (*Riparia riparia*)	0.0		0.2	0.0-0.5	NS
Barn swallow (*Hirundo rustica*)	0.0		0.2	0.0-1.1	NS
Blue jay (*Cyanocitta cristata*)	10.6	9.2-13.0	8.0	6.0-10.4	NS
American crow (*Corvus brachyrhynchos*)	9.2	5.9-14.0	18.9	15.3-23.5	*
Carolina chickadee (*Parus carolinensis*)	10.1	4.3-13.5	7.1	3.3-13.1	NS
Tufted titmouse (*Parus bicolor*)	21.3	16.8-23.8	18.9	15.8-24.0	NS
White-breasted nuthatch (*Sitta carolinensis*)	4.9	1.6-7.6	7.1	6.0-8.2	NS

TABLE 1.—Continued

	Salt Creek		Patoka River		
Bird species	Mean	Range	Mean	Range	P[a]
Carolina wren (*Thryothorus ludovicianus*)	0.5	0.5	5.6	1.6-12.0	NS
Blue-gray gnatcatcher (*Polioptila caerulea*)	3.4	1.1-6.5	20.8	16.9-24.0	**
Eastern bluebird (*Sialia sialis*)	0.2	0.0-0.5	0.7	0.0-2.2	NS
Wood thrush (*Hylocichla mustelina*)	1.3	1.1-1.6	0.4	0.0-1.1	NS
American robin (*Turdus migratorius*)	5.4	3.2-8.6	0.7	0.0-1.6	NS
Gray catbird (*Dumetella carolinensis*)	1.4	1.1-2.2	0.5	0.0-1.1	NS
Brown thrasher (*Toxostoma rufum*)	0.2	0.0-0.5	0.0		NS
Cedar waxwing (*Bombycilla cedrorum*)	0.2	0.0-0.5	0.0		NS
European starling (*Sturnus vulgaris*)	1.1	0.0-2.2	0.0		NS
White-eyed vireo (*Vireo griseus*)	0.7	0.5-1.1	1.8	1.1-2.7	NS
Warbling vireo (*Vireo gilvus*)	1.4	1.1-1.6	0.0		**
Red-eyed vireo (*Vireo olivaceus*)	6.7	6.5-7.0	12.9	9.3-14.7	*
Northern parula (*Parula americana*)	1.8	0.5-3.2	9.1	4.9-12.0	*
Yellow-throated warbler (*Dendroica dominica*)	2.9	0.5-5.9	4.7	1.1-7.1	NS
Prairie warbler (*Dendroica discolor*)	0.2	0.0-0.5	0.0		NS
Cerulean warbler (*Dendroica cerulea*)	0.4	0.0-1.1	9.1	7.1-12.6	**
American redstart (*Setophaga ruticilla*)	0.0		5.6	3.8-7.1	**
Prothonotary warbler (*Protonotaria citrea*)	11.2	9.7-14.0	19.8	13.7-24.6	NS
Ovenbird (*Seiurus aurocapillus*)	0.2	0.0-0.5	0.2	0.0-0.5	NS
Louisiana waterthrush (*Seiurus motacilla*)	0.0		0.7	0.0-1.1	NS
Kentucky warbler (*Oporornis formosus*)	1.1	0.5-1.6	3.1	2.7-3.8	*
Common yellowthroat (*Geothlypis trichas*)	13.9	8.1-17.3	18.2	16.4-19.7	NS
Yellow-breasted chat (*Icteria virens*)	0.7	0.5-1.1	2.7	1.1-3.8	NS
Summer tanager (*Piranga rubra*)	0.2	0.0-0.5	0.5	0.0-1.6	NS
Scarlet tanager (*Piranga olivacea*)	1.1	0.5-1.6	2.2	0.0-4.4	NS
Northern cardinal (*Cardinalis cardinalis*)	13.9	9.2-17.8	10.7	9.8-11.5	NS
Indigo bunting (*Passerina cyanea*)	24.1	18.4-30.3	35.7	24.6-49.7	NS
Rufous-sided towhee (*Pipilo erythrophthalmus*)	0.5	0.0-1.1	1.1	0.0-2.7	NS
Field sparrow (*Spizella pusilla*)	0.9	0.0-1.6	0.5	0.0-1.1	NS

TABLE 1.—Continued

Bird species	Salt Creek Mean	Salt Creek Range	Patoka River Mean	Patoka River Range	P[a]
Song sparrow (*Melospiza melodia*)	4.9	3.8-5.9	0.0		**
Red-winged blackbird (*Agelaius phoeniceus*)	8.3	2.7-14.0	1.1	0.5-1.6	NS
Eastern meadowlark (*Sturnella magna*)	1.6	0.5-2.7	0.0		NS
Common grackle (*Quiscalus quiscula*)	22.7	9.7-33.5	2.7	0.5-5.5	*
Brown-headed cowbird (*Molothrus ater*)	5.6	3.2-7.0	8.7	7.6-9.8	NS
Orchard oriole (*Icterus spurius*)	0.0		0.2	0.0-0.5	NS
Northern oriole (*Icterus galbula*)	1.1	0.0-2.7	0.4	0.0-1.1	NS
American goldfinch (*Carduelis tristis*)	1.1	1.1	2.5	2.2-2.7	**

[a] Statistical significance of t tests: NS ($P > 0.05$), * ($P < 0.05$), ** ($P < 0.01$), *** ($P < 0.001$).

richness was similar for Salt Creek (mean = 53.3 species) and the Patoka River (mean = 52.0 species). Cluster analyses of surveys produced similar results no matter which clustering method or dissimilarity index was used. Dendrograms generated by each method linked all Salt Creek surveys together and all Patoka River surveys before Salt Creek and Patoka River surveys were combined (Figure 1). Coefficients of determination (r^2) for Salt Creek survey pairs ranged from 0.74-0.77 and were 0.74-0.83 for Patoka River pairs. Variation explained using correlations between pairs of Salt Creek and Patoka River surveys ranged from 24-65%. Thus, both waterways have similar avifaunas, but each is distinctive from each other.

Comparisons among bird species should be made with caution due to differences in their detectability. Bird species vary in their degree of conspicuousness and frequency and loudness of vocalizations. Thus, the most commonly detected species may not necessarily have had the greatest population densities. Overall, the most commonly detected species were the indigo bunting (refer to Table 1 for scientific names), wood duck, aca-

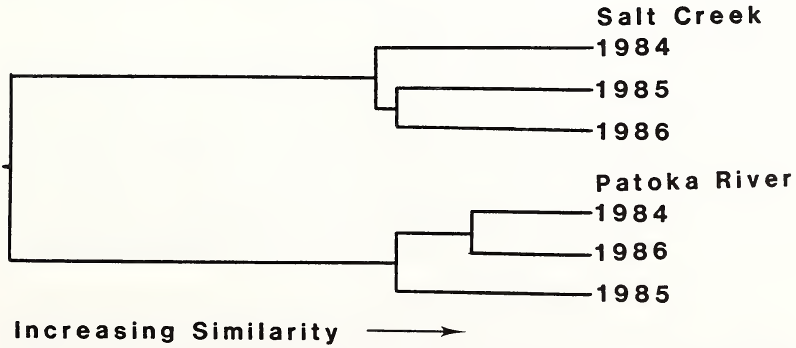


FIGURE 1. Dendrogram showing cluster analysis of six avian surveys, 1984-1986. The average linkage clustering method was used and coefficients of determination ($1 - r^2$) were used as the measure of dissimilarity.

dian flycatcher, tufted titmouse, eastern wood-pewee, common yellowthroat, and prothonotary warbler (Table 1). Only two of these species (wood duck, prothonotary warbler) could be considered wetland obligates. Indigo buntings and common yellowthroats prefer woodland edges and shrublands. Their high rate of occurrence reflects the ecotone provided by the stream channel. The remaining three species are commonly found in upland forests and may obtain high densities along wooded riparian corridors due to the continuity and extent of woodlands.

T-tests between areas for each species showed numbers of individuals detected was significantly greater for twelve species along the Patoka River compared to five species along Salt Creek (Table 1). An additional ten species were unique to the Patoka River and nine other birds were found only along Salt Creek. Generally, species more abundant along the Patoka River were those requiring woodland or woodland edges. Birds whose typical habitats are non-wooded or are associated with man were more commonly found along Salt Creek. A previous study has predicted the impacts of several habitat alterations on birds present in forested riparian areas (5).

Numbers of wood ducks were consistently higher along Salt Creek, although the Patoka River system appears to provide superior habitat. The availability of wetlands away from the Patoka Rive channel may account for this. Natural oxbows and numerous impoundments of small drainages caused by beaver (*Castor canadensis*) within the last decade are much more prevalent along the Patoka River. Sloughs, oxbows, and flooded timber may offer more optimal production areas for wood ducks compared to river channels subject to restricted flow. Numbers of wood ducks counted along the Patoka River have declined since the construction of Patoka Reservoir. Moser (3) found inverse correlations between breeding indices along streams in Indiana with other independent production estimates. He felt that wood ducks may be forced to use streams to a greater extent when low water levels limit the number of ephemeral wetland habitats elsewhere.

Only two birds found along the stream segments in this study are considered endangered, threatened, or of special concern by the Indiana Division of Fish and Wildlife. The yellow-crowned night-heron is listed as threatened in Indiana and the red-shouldered hawk is of special concern due to loss of wooded riparian habitat. Few nesting sites are presently known for yellow-crowned night-herons in Indiana. They have nested previously along this segment of the Patoka River, but may have abandoned their nest site due to disturbances from mining and the loss of timber from stream modifications conducted by the U.S. Army Corps of Engineers. Used nests recently found away from the stream channel indicate that a population continues to breed along the Patoka River. Although red-shouldered hawks breed in upland forests throughout Indiana, nesting densities are thought to be greatest along the Patoka River.

Both stream segments supported populations of all six woodpecker species that nest in southern Indiana. Discounting the least commonly detected hairy woodpecker, numbers of each woodpecker species, except for the northern flicker, were greater along the Patoka River. Northern flickers prefer the most open and least forested habitats of this group. The higher occurrence rate of the remaining species reflects the greater extent of forest and the number of trees suitable for constructing roosting and nesting cavities. An additional eleven birds in Table 1 utilize cavities for nesting (4). Although patterns of occurrence between stream segments are less clear, the numbers indicate that riparian woodlands are used by many cavity-nesting birds.

A wetland bird species notable for its absence during these surveys was the spotted sandpiper (*Actitus macularia*). This may be due to more constant water flow resulting from the operations of upstream reservoirs, which reduces the number of gravel and sandbars favored by spotted sandpipers.

Although the Patoka River contains a more representative woodland avifauna than

Salt Creek, habitat along the Patoka River has not been free from human disturbances. Much of the woodland adjacent to the Patoka River has been logged within the last decade, but conversion to crop fields has not taken place to any great extent. Mining of coal has occurred in close proximity to the Patoka River. The U.S. Army Corps of Engineers has cleared some sections of log jams and removed some streamside trees. The operation of the dam at Patoka Reservoir will continue to influence the quality of wildlife habitat along the Patoka River. To preserve the diverse wildlife community, protection and management of habitats adjacent to the river channel is necessary.

Acknowledgments

R.E. Rolley provided statistical assistance. The study was conducted incidental to a project funded by Federal Aid to Wildlife Restoration Project W-26-R and the Indiana Division of Fish and Wildlife.

Summary

During June 1984-1986, birds were surveyed once annually from a canoe along 18.5 km of Salt Creek, Lawrence County, and 18.3 km of the Patoka River, Pike County, Indiana. A total of 77 avian species was detected and average species richness per survey was similar between river segments (means = 53.3, 52.0). The most commonly detected species were indigo bunting, wood duck, acadian flycatcher, tufted titmouse, eastern wood-pewee, common yellowthroat, and prothonotary warbler. Riparian woodlands provide habitat for a large variety of birds, many of which are uncommon in other habitats. Although both streams shared many birds in common, the number of individuals differed for many species between river segments. The Patoka River supported greater diversity and numbers of woodland species. This is attributed to less encroachment on the riparian corridor by agricultural development and other human activities.

Literature Cited

1. Best, L.B., D.F. Stauffer, and A.R. Geier. 1979. Evaluating the effects of habitat alteration on birds and small mammals occupying riparian communities. Pages 117-124 *in* R.R. Johnson and J.F. McCormick, eds. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. U.S.D.A. For. Serv. Gen. Tech. Rep. WO-12.
2. Fredrickson, L.H., and F.A. Reid. 1986. Wetland and riparian habitats: a nongame management overview. Pages 59-96 *in* J.B. Hale, L.B. Best, and R.L. Clawson, eds. Management of nongame wildlife in the Midwest: a developing art. North Central Section of The Wildlife Society.
3. Moser, T.J. 1986. Stream wood duck surveys as production indices. Indiana Div. Fish and Wildl. Manage. Res. Note 362. 6 pp.
4. Scot, V.E., K.E. Evans, D.R. Patton, and C.P. Stone. 1977. Cavity-nesting birds of North American forests. U.S.D.A. For. Serv. Agric. Handbook 511. 112 pp.
5. Stauffer, D.F., and L.B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44:1-15.
6. Swift, B.L. 1984. Status of riparian ecosystems in the United States. Water Resour. Bull. 20:223-228.

Tree Regeneration Response to Clearcutting on the USFS Brownstown Ranger District

B.C. Fischer, J.A. Kershaw, Jr., D.W. George, C.A. George and W.L. Mills
Department of Forestry and Natural Resources
Purdue University
West Lafayette, Indiana 47907

Introduction

In 1969 the United States Forest Service (USFS) Hoosier National Forest adopted even-aged silviculture using clearcut harvesting with natural regeneration as the forest management system for upland central hardwoods. This decision was based on over 20 years of research summarized in a handbook by Roach and Gingrich (8). They conclude that "upland hardwoods are best suited to even-aged silviculture" and "clearcutting should be used for regeneration." In recent years a number of forest managers have indicated that when upland central hardwood stands, which are oak (Quercus spp.) dominated, are clearcut they regenerate primarily to non-oak species, particularly on the better sites.

Only recently have researchers in Indiana and Ohio begun to examine clearcuts and quantify the situation. Hilt (5) studied 29 clearcuts (18 in southeastern Ohio, 7 in eastern Kentucky and 4 in south central Indiana) ranging from 5 to 26 years of age and found that only on the poorer sites is oak successfully regenerating. On the better sites mixtures of yellow-poplar (Liriodendron tulipifera), red maple (Acer rubrum), bigtooth aspen (Populus grandidentata) and white ash (Fraxinus americana) are dominating. Heiligmann, et. al. (4) found in a study of 28-year-old reproduction on clearcuts in southeastern Ohio that the proportion of oak regeneration was significantly lower than the oak composition of the original stand. Many of Indiana's professional foresters suggest that similar results would be found for Indiana clearcuts.

The objectives of this study were: 1) to determine the tree and vine regeneration response to clearcut harvesting on the USFS Hoosier National Forest, Brownstown Ranger District, and 2) compare species composition on these clearcuts to the original stand composition (sawtimber volume) and site quality.

Study Sites

Clearcuts of mature, upland hardwood stands made prior to 1982 in the Pleasant Run and Lost River Management Units of the USFS Brownstown Ranger District were identified from office records. Those clearcuts with complete records that included age, acreage, cut volume by species group, and location were selected for field study and are listed in Table 1. Data on advance regeneration before clearcutting was not available.

Figure 1 shows the location of the Pleasant Run and Lost River Units of the Brownstown Ranger District. The summary by Homoya, et. al. (6) on the natural regions of Indiana clearly delineates the similarities and differences between the features of these units.

The Pleasant Run Unit is located in the Highland Rim Natural Region, Brown County Hills Section - 10B. This section features deeply dissected uplands underlain by siltstone, shale and sandstone. It is in Indiana Soil Region 11 and is characterized by well drained acid silt loam soils of the Berks-Gilpin-Weikert Association (7). The Weikert soil series is the shallowest soil in the region. The characteristic forest vegetation on the uplands is oak-hickory with typical upper slopes having stands dominated by chestnut oak (Q. prinus) and greenbriar (Smilax spp.). Ravines contain mesic species such as American beech (Fagus grandifolia), red oak (Q. rubra), sugar maple (Acer saccharum) and white ash.

The Lost River Unit lies within the Shawnee Hills Natural Region, Crawford Upland

TABLE 1. Percent species composition by harvest sawlog volume for sampled clearcuts on the Pleasant Run and Lost River units of the USFS Brownstown Ranger District.

			Percent Sawlog Volume					
Clearcut Name and	No.	Age	White Oak	R & B Oak	Other Oak	Yellow-poplar	Ash & Other	Mixed Hdwd
Pleasant Run Unit								
Knob Creek	1	15	5	9	16	2	0	69
Henderson Creek	1	14	14	22	3	9	0	52
Henderson Creek	2	14	19	41	20	6	0	14
Cope Hollow	1	12	35	28	6	5	0	26
Jackie Branch	2	12	40	29	5	5	0	22
Moore Hollow	1	12	9	5	7	22	0	57
Jackie Branch	1	12	24	40	27	3	0	6
Cope Hollow	2	11	33	35	16	5	0	12
Kurtz Road	1	11	36	40	1	0	0	24
South Hickory Ridge	3	11	13	18	34	4	0	30
Berry Ridge	1	10	29	21	40	1	0	10
Berry Ridge	2	10	6	20	11	9	0	53
South Hickory Ridge	2	9	7	23	49	7	0	15
Ponderosa Camp	2	8	11	24	58	0	0	8
Skin Ridge	1	8	18	5	5	16	0	57
Berry Ridge	3	7	24	34	27	10	1	5
Berry Ridge	2	7	10	24	21	26	1	18
Berry Ridge	1	7	14	36	16	10	5	19
Hillenburg Cemetery	1	7	37	24	12	1	1	26
South Hickory Ridge	1	7	14	9	44	12	0	21
Wt. Average*			19	23	22	8	0	29
Lost River Unit								
Union Cemetery	1	16	16	20	0	18	0	45
Union Cemetery	2	15	27	23	1	10	1	38
Union Cemetery	4	15	17	20	4	10	1	48
Union Cemetery	3	15	40	33	1	14	0	12
Beaver Creek	1	14	19	28	14	0	0	40
Pleasant View	2	14	16	8	0	16	0	61
Beaver Creek	3	14	21	29	2	19	1	29
Beaver Creek	2	14	30	14	4	5	3	45
Pleasant View	3	14	15	22	5	11	0	48
Carpenter Tract	3	13	11	23	2	15	0	49
Shirley Creek	1	10	34	20	4	9	0	33
Bonds Chapel	1	7	15	48	0	13	1	24
Bonds Chapel	2	7	35	21	0	6	0	37
Georgia Tract	1	7	18	14	1	7	6	54
Georgia Tract	2	7	13	19	2	41	6	20
Yenne Tract	3	6	7	22	2	30	4	36
Sulphur Creek	1	6	25	40	0	11	0	25
Wt. Average*			20	23	2	14	2	39

* Based on acreage

Section - 9A. This section features rugged hills with sandstone cliffs and rockhouses. The characteristic soils of this section are well drained acid silt loams of the Wellston-Zanesville-Berks Association. They are moderately deep to deep and are in Indiana Soil Region 11 (7). The characteristic forest vegetation on the upper slopes is an oak-hickory assortment with black (Q. velutina), white (Q. alba), chestnut and scarlet oak (Q. coccinea), and assorted hickories (Carya spp.). The cove forests most resemble the mixed

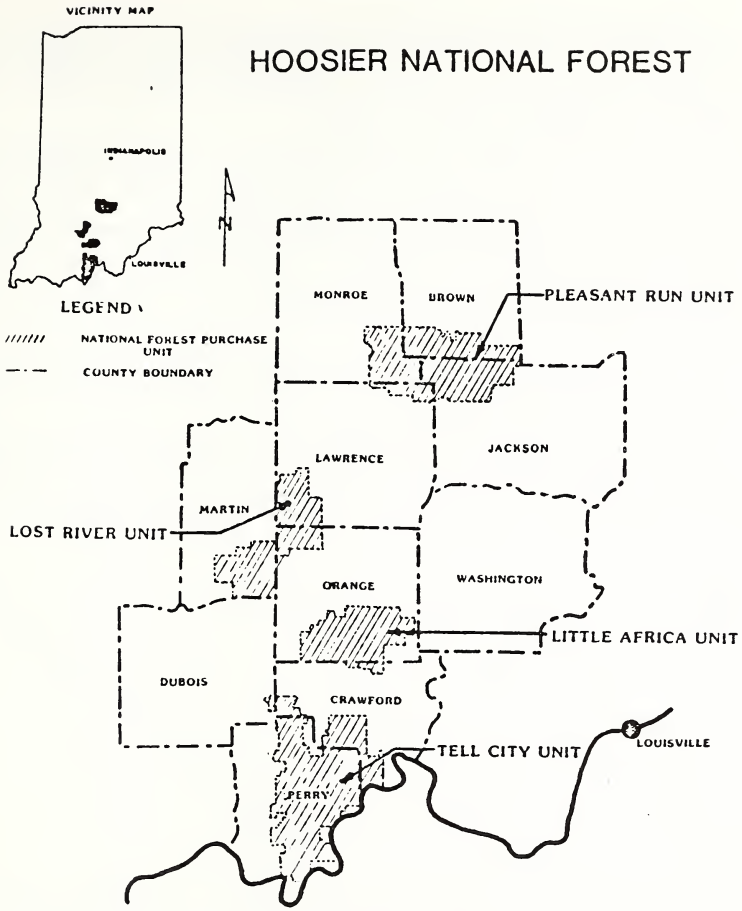


FIGURE 1. Location of the management units on the USFS Hoosier National Forest.

mesophytic type with characteristic species being American beech, yellow-poplar, red oak, sugar maple, black walnut (Juglans nigra) and white ash.

Based on these descriptions of the two units it can be concluded that the Pleasant Run Unit is located on drier sites than the Lost River Unit, and this is reflected in the different composition of tree species that dominate the two units.

Methods

Data Collection

Sampling on each clearcut was done using 1/100-acre circular plots with each plot center permanently marked with a 16-inch orange plastic surveyor's stake. A three chain, square grid systematic sampling system was chosen to obtain approximately a one percent minimum sampling intensity per clearcut. Sampling commenced using a random start for each clearcut. Plots overlapping the edge of the clearcut were not sampled.

Clearcut size ranged from 10 to 43 acres and averaged 22 acres for the 37 sampled clearcuts. Sample intensity averaged 1.2 percent and varied from 0.9 to 1.9 percent. For the Pleasant Run Unit 20 clearcuts, totaling 404 acres and 477 plots were sampled. The Lost River Unit sample was 17 clearcuts, totaling 418 acres and 502 plots. All data were collected between July 1986 and October 1986.

On each plot regeneration, wild grapevine (vitis spp.) and site factor data were collected. All regeneration greater than breast height (4.5 feet) were sampled. Residual trees left from the previous forest were recorded separately. Each woody plant was recorded by species, crown position (dominant, codominant or suppressed) and origin (seedling, seedling sprout or stump sprout). Codominant trees were classified as trees whose crowns were part of the main canopy, while dominants were classified as trees with crowns above the main canopy and suppressed trees were classified as individuals with crowns below the canopy.

A tally of the number of wild grapevines in the main canopy on each regeneration plot was recorded. A grapevine was tallied if it was rooted within the plot and then directly entered the crown of a tree in the plot (10).

On each plot the aspect and slope position code were determined. Aspect was expressed in degrees of azimuth measured clockwise from true north to the nearest 10 degrees. Slope position code was determined for each plot using the system developed by Bowersox and Ward (2), which is based on slope curvature and shown in Figure 2.

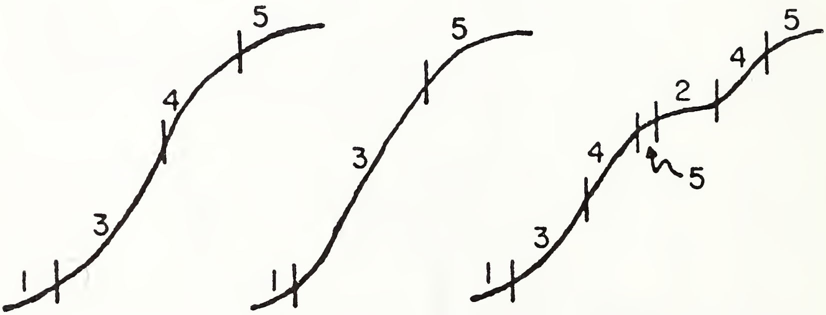


FIGURE 2. From Bowersox and Ward, 1972: Slope position code numbers for typical topography of the ridge and valley region of Pennsylvania.

Analysis

For analysis purposes, data from the clearcuts were summarized within each of the two USFS management units as shown in Table 1. The data were not combined because each of the management units was located in different and distinct Indiana natural region. Only the stems of tree species in the dominant and codominant crown classes on each 1/100-acre plot were used in the analysis. Non-commercial tree species such as American hornbeam (Carpinus caroliniana), serviceberry (Amelanchier arborea), redbud (Cercis canadensis), devils-walking-stick (Aralia spinosa), dogwoods (Cornus spp.), hawthorns (Crataegus spp.), eastern hophornbeam (Ostrya virginiana), sumac (Rhus spp.), pawpaw (Asimina triloba) and miscellaneous shrubs were also excluded. The dominant-codominant commercial tree species data consisted of 7,778 stems (total stems recorded = 20,472) on the Pleasant Run Unit and 8,641 stems (total = 23,637) on the Lost River Unit.

To analyze species composition the dominant-codominant tree species were divided into 6 species groups consisting of: 1) white oak (white and chinkapin oak (Q. muehlenbergii)); 2) red and black oak; 3) other oak (chestnut, scarlet, pin (Q. palustris)

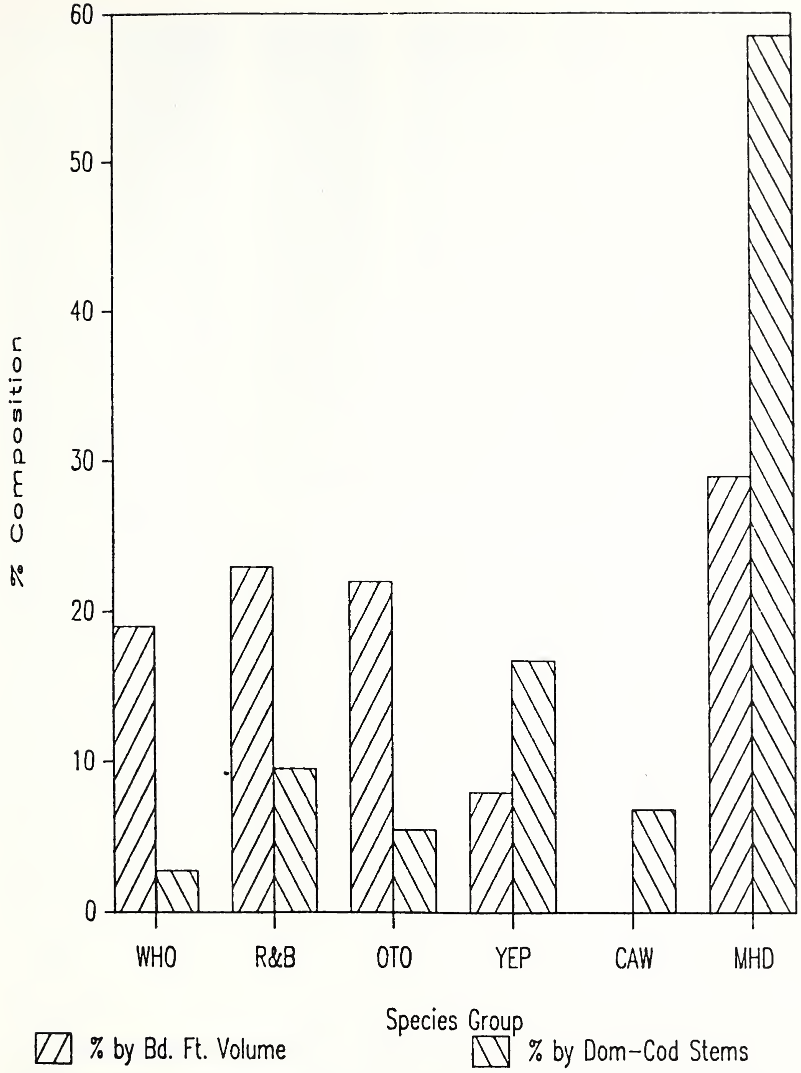


FIGURE 3. Comparison of percent species composition by preharvest sawtimber volume to dominant-codominant regeneration on the Pleasant Run Unit of the USFS Brownstown Ranger District.

and post (Q. stellata)); 4) yellow-poplar; 5) cherry-ash-walnut (black cherry (Prunus serotina), ash and black walnut); and 6) mixed hardwoods (primarily bigtooth aspen, American beech, red elm (Ulmus rubra), hickories, red and sugar maple, and sassafras (Sassafras albidum). Since the number of regeneration stems per acre is a function of stand age and site quality, percentages were used to analyze species composition. The weighted average of the dominant-codominant stems was determined for each of the six species groups and expressed as a percent (Figures 3-8).

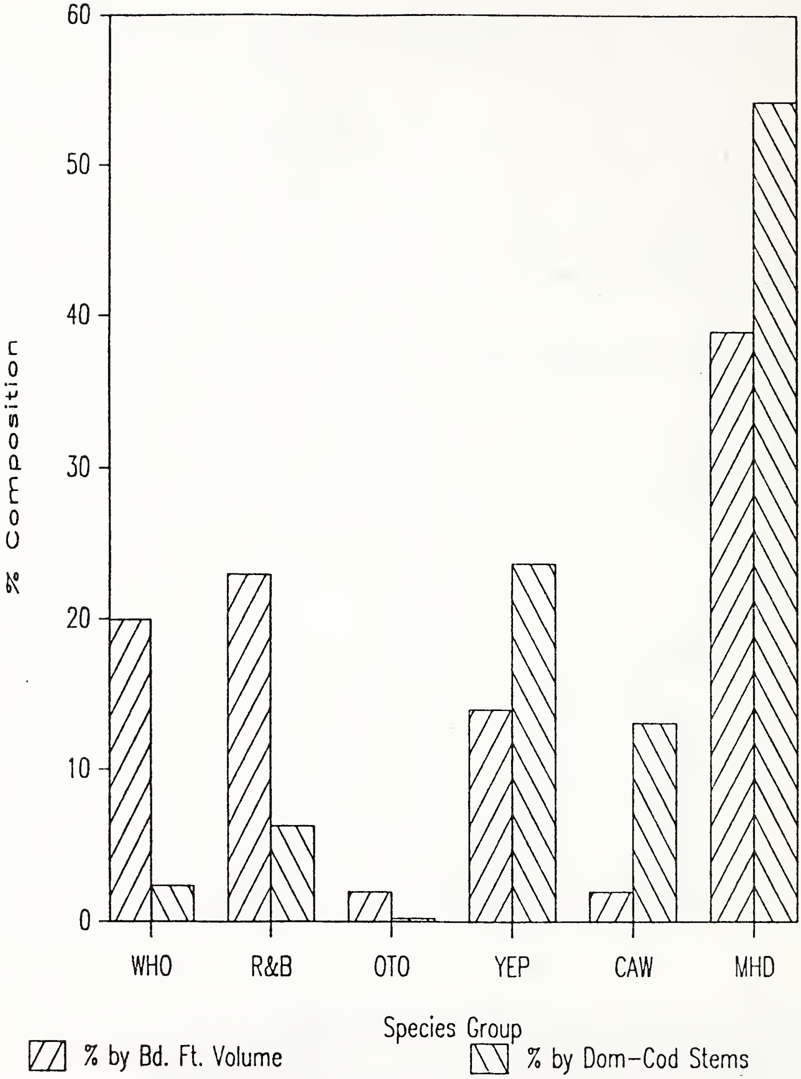


FIGURE 4. Comparison of percent species composition by preharvest sawtimber volume to dominant-codominant regeneration on the Lost River Unit of the USFS Brownstown Ranger District.

Timber sale records for each clearcut were summarized for sawtimber volume (board feet) and the percent volume by species group was calculated. These percentages are shown in Table 1.

For the analysis the aspect for each plot was reduced to a 1 to 5 scale using a modification of Beers et al. (1) aspect transformation procedure:

$A' = (\mathrm{COS}\ (45 - A) + 1) \times 2 + 1$

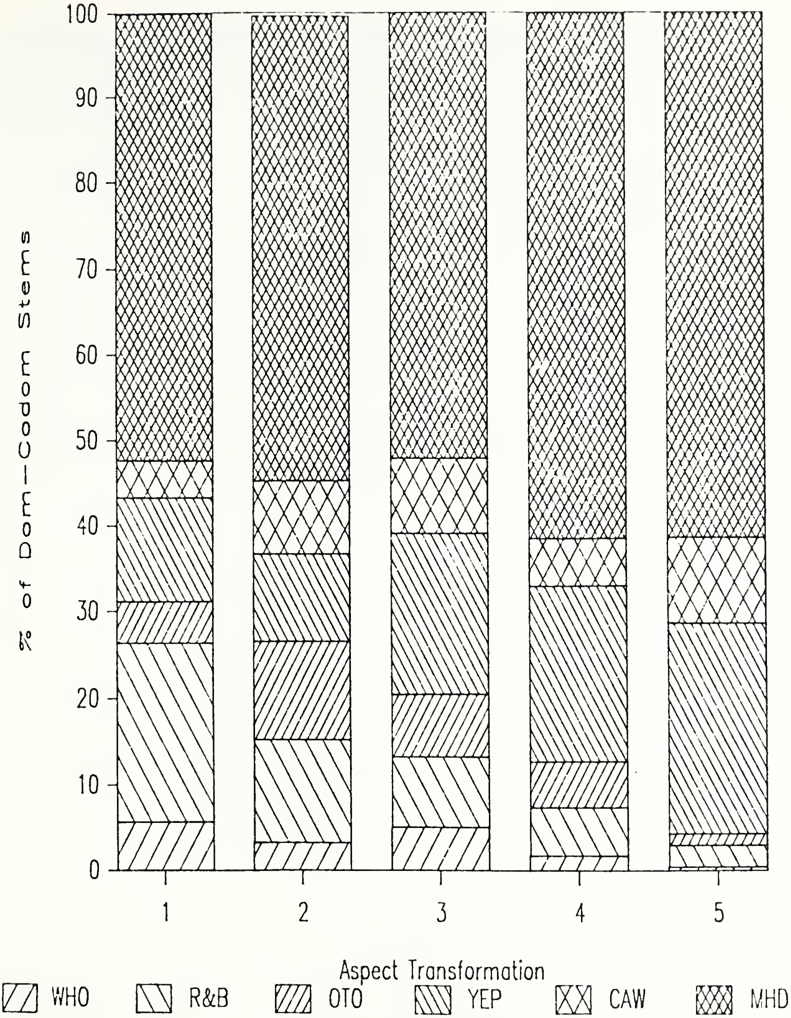


FIGURE 5. Percent species composition by aspect code for dominant-codominant regeneration on the Pleasant Run Unit of the USFS Brownstown Ranger District.

where A′ = aspect code, COS = cosine, and A is aspect in degrees of azimuth

After transformation an azimuth of 190 to 260 has an aspect code (A′) of 1, an azimuth of 150 to 180 or 270 to 300, has an aspect code 2, an azimuth of 130 to 140 or 310 to 320 has an aspect code 3, an azimuth of 90 to 120 or 330 to 0 has an aspect code 4 and an azimuth of 10 to 80 has an aspect code 5. This transformation is reasonable because forest growth is usually considered to be greater on northern and eastern slopes. Several studies in the oak-hickory type support this concept (3).

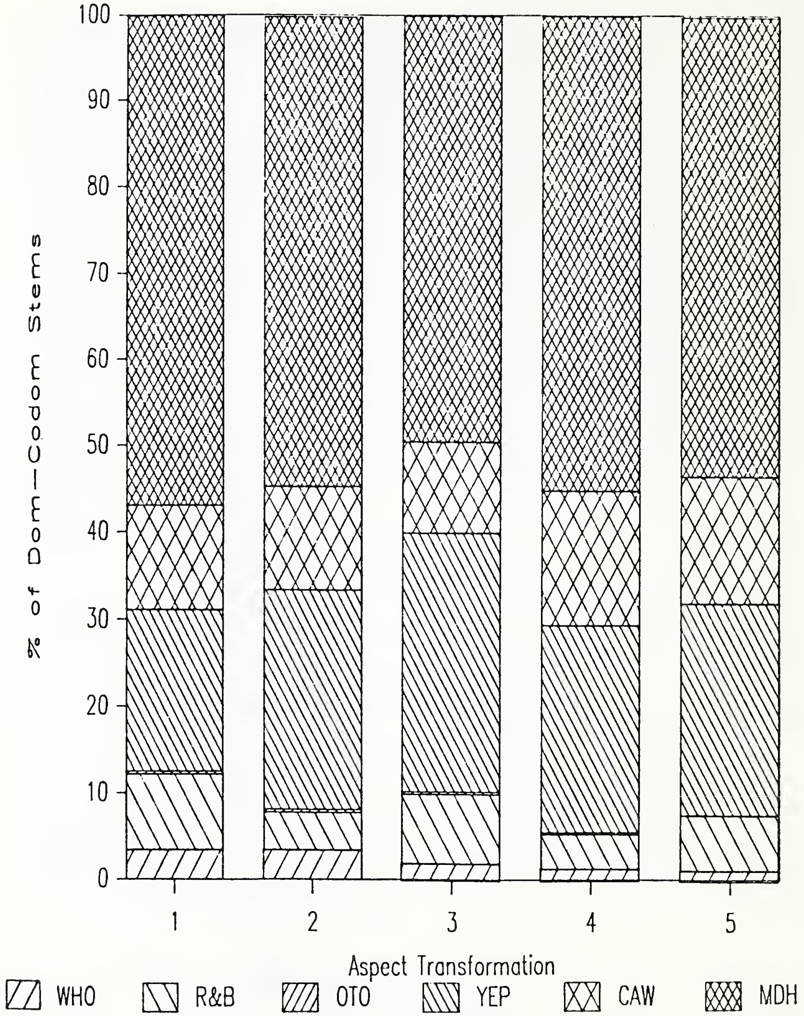


FIGURE 6. Percent species composition by aspect code for dominant-codominant regeneration on the Lost River Unit of the USFS Brownstown Ranger District.

Results and Discussion

The number of stems per acre in the dominant and codominant crown classes for tree species ranged from 628 (12 years old clearcut) to 2031 (7 year old clearcut) for the Pleasant Run Unit and from 494 (14 year old clearcut) to 2566 (7 year old clearcut) for the Lost River Unit. The average clearcut age and number of dominant-codominant stems per acre for each unit was 10 years and 1144 stems for Pleasant Run, and 11 years and 1480 stems for Lost River. These averages are comparable to those found by Hilt (5). Also, as expected the number of dominant-codominant stems decreased as age increased.

A comparison of the percent species composition before clearcutting (sawtimber

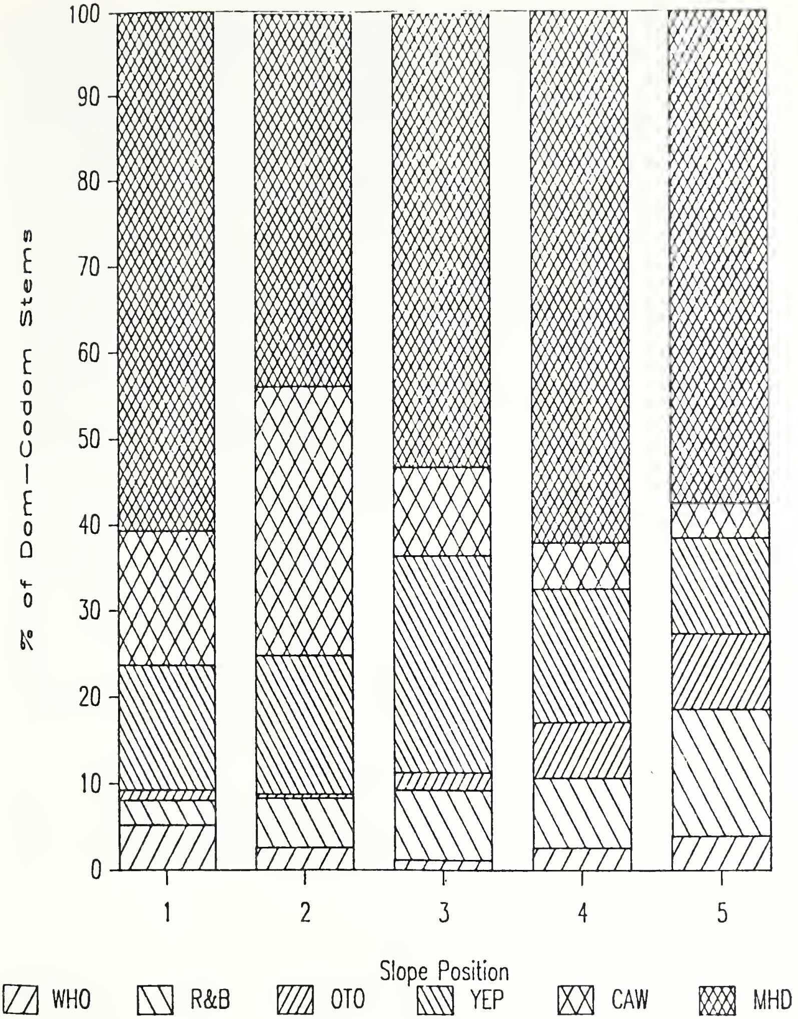


FIGURE 7. Percent species composition by slope position code for dominant-codominant regeneration on the Pleasant Run Unit of the USFS Brownstown Ranger District.

volume) and after clearcutting (dominant-codominant stems) is shown in Figures 3 and 4 for the two units. In both units the percentage of white oak (WHO), red and black oak (R&B) and other oak (OTO) is much lower in the regeneration layer, and the yellow-poplar (YEP), black cherry, ash and black walnut (CAW), and mixed hardwoods (MHD) are much higher. There is a higher percentage of other oak, primarily chestnut oak, in the Pleasant Run Unit both before and after clearcutting.

Figures 5 and 6 show the percent species composition for the regeneration on the two management units by aspect code. The trend of decreasing amounts of total oak (WHO + R&B + OTO) with aspect changing from southwest (aspect code 1) to north-

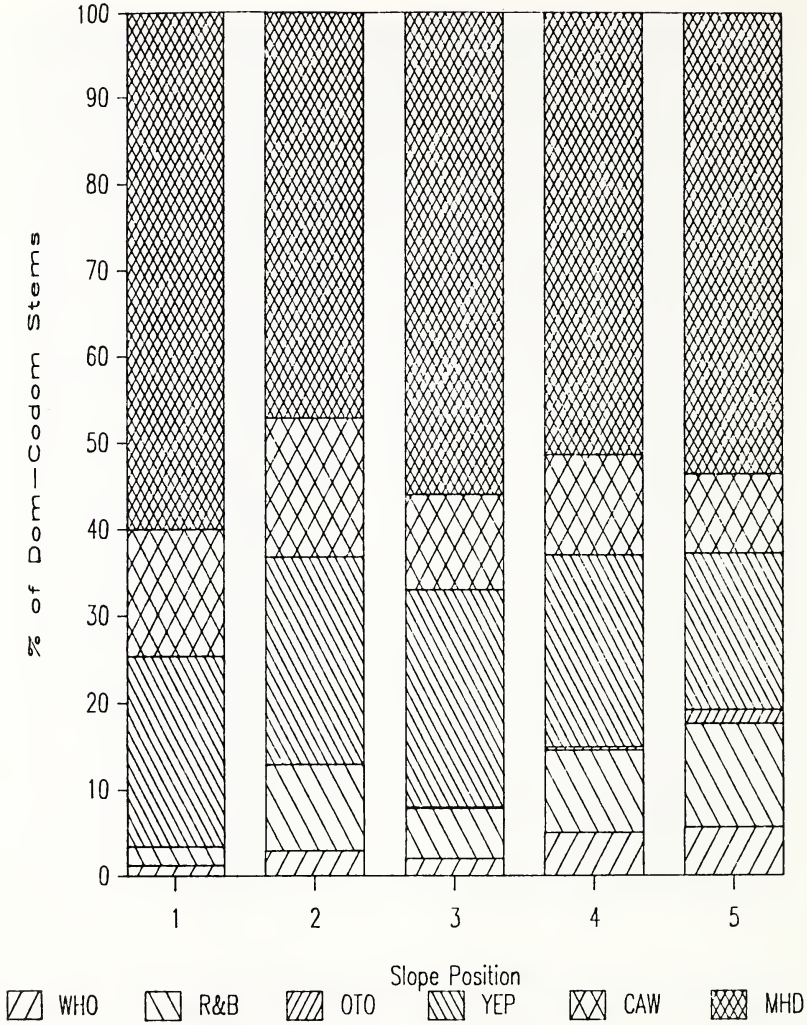


FIGURE 8. Percent species composition by slope position code for dominant-codominant regeneration on the Lost River Unit of the USFS Brownstown Ranger District.

east (aspect code 5) is evident on the Pleasant Run Unit (Figure 5). The Lost River Unit has lower percentages of oak and higher percentages of yellow-poplar and cherry-ash-walnut than the Pleasant Run Unit for all aspect codes (Figure 6). The percentage of oak is highest on aspect code 1, while the percentage of yellow-poplar plus cherry-ash-walnut is lowest on aspect code 1 for both units (Figures 5 and 6). The percentages of mixed hardwoods ranges from 50 to 60+ percent on all aspect codes for both units. Other oaks, primarily chestnut oak, was absent in aspect code 5, the best site in terms of aspect, on the Lost River Unit (Figure 6).

Figures 7 and 8 show the percent species composition for the regeneration on the two management units by slope position. The trends for oak regeneration are again more pronounced for the Pleasant Run Unit with the oak composition increasing from the lower slopes, position 1, to ridge tops, position 5, (Figure 7). For the Lost River Unit other oaks are only evident on slope positions greater than 2 (Figure 8). Yellow-poplar percentages were lowest on slope position 5 for both units, but appreciable on all slope positions. For both units, slope position 2 (benches, which should have more moisture), appears to have a different species composition than all other slope positions. The percentage of cherry-ash-walnut is greatest on this slope position and the mixed hardwood percentage is lowest.

In a similar study, Hilt (5) found that for clearcuts 6 to 15 years of age (the age range of this study) that the percentage of oak regeneration in the dominant-codominant class was fairly consistent (22-31 percent) regardless of site. We found lower percentages of oak than Hilt and a difference between the two management units with an average of 19 percent oak for Pleasant Run and 8 percent oak for Lost River. However, Hilt only selected clearcuts composed of at least 60 percent upland oaks (by volume) prior to harvest while our study sites contained much less preharvest oak volume, averaging 64 percent oak by sawtimber volume for Pleasant Run and only 45 percent for Lost River (Table 1).

Finally, we found that wild grapevines were a major vegetation component of the regeneration, and actually dominated a number of plots and a few clearcuts. The number of grapevines averaged 336 per acre for Pleasant Run and 530 per acre for Lost River. Averages per clearcut ranged from 148 to 1068 grapevines per acre for Pleasant Run and 174 to 988 per acre for Lost River. No preharvest grapevine control was done in any of these clearcuts. Standiford and Fischer (10) found that 12-15 years following patch clearcutting of upland hardwoods stands at the Southern Indiana Purdue Agricultural Center, in Dubois County, Indiana, grapevines averaged 236 per acre. These stands were similar in stocking and treatment to those in this study. To our knowledge, no other grapevine data exists for clearcut sites in Indiana.

Smith and Lamson (9) have summarized research on wild grapevines in immature Appalachian hardwoods. In sapling stands (average diameter at breast height less than 5 inches) managed for timber production they suggest that "50 grapevines per acre is the most that they would want." For sapling stands they estimate that 300 grapevines per acre would represent 25 percent of the stand area occupied by grapevines, and 500 grapevines represents 40 percent coverage. We found that the range of 150 to 1050 grapevines per acre would represent 14 to 82 percent of the stand area according to these authors.

Conclusions

Clearcuts made 6 to 16 years ago on the Brownstown Ranger District are regenerating to mixed species stands. The species composition of the dominant-codominant regeneration layer appears to be influenced by natural region with the drier sits of the Pleasant Run Unit (Highland Rim Natural Region - Brown County Hills Section) regenerating more to oak species than those on the Lost River Unit (Shawnee Hills Natural Region - Crawford Upland Section). The harvested sawtimber volumes from these units reflects a similar difference with higher percentages of oak on the Pleasant Run Unit.

Sites with northeastern aspects or a lower slope position (better sites) have lower percentages of oak and higher percentages of yellow-poplar and cherry-ash-walnut than southwest facing sites or a upper slope/ridge slope positions. Wild grapevines are regenerating in larger numbers on all clearcuts and may present a timber management problem.

Acknowledgments

This study was supported by funding from the United States Forest Service, Wayne-Hoosier National Forest, Bedford, Indiana.

Literature Cited

1. Beers, T.W., P.E. Dress and L.C. Wensel. 1966. Aspect transformation in site productivity research. Journal Forestry 64(10):691-692.
2. Bowersox, T.W. and W.W. Ward. 1972. Prediction of oak site index in the ridge and valley region of Pennsylvania. Forest Science 18:192-195.
3. Hartung, R.E. and W.J. Lloyd. 1969. Influence of aspect on forests of the Clarksville soils in Dent County, Missouri. Journal Forestry 67(3):178-182.
4. Heiligmann, R.B., E.R. Norlund, and D.E. Hilt. 1985. 28-year-old reproduction on five cutting practices in upland oaks. Northern Journal of Applied Forestry 2(1): 17-22.
5. Hilt, D.E. 1985. Species composition of young central hardwood stands that develop after clearcutting. Proceedings Fifth Central Hardwood Forest Conference, University of Illinois, Urbana. p. 11-14.
6. Homoya, M.A., D.B. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Proceedings Indiana Academy of Science 94:245-268.
7. IDNR. 1984. Indiana Forest Soils Handbook. Indiana Department of Natural Resources, Division of Forestry.
8. Roach, B.A. and S.F. Gingrich. 1968. Even-aged silviculture for upland central hardwoods. USDA Forest Service, Agricultural Handbook 355, 39p.
9. Smith, H.D. and N.I. Lamson. 1986. Wild grapevines — A special problem in immature Appalachian hardwood stands. Proceedings Workshop on Guidelines for Managing Immature Appalachian Hardwood Stands, Morgantown, WV. p. 228-239.
10. Standiford, R.B. and B.C. Fischer. 1980. Fifteen year results of three harvesting methods on composition and development of regeneration in southern Indiana upland hardwoods. Proceedings Third Central Hardwood Forest Conference, University of Missouri-Columbia, p. 408-419.

Indiana's Property Tax Incentive Program for Wildlife Habitat Protection

David Howell
Indiana Division of Fish and Wildlife
Box 393, Winslow, Indiana 47598
Donald E. Buckland
Indiana Division of Fish and Wildlife
Box 404, Spencer, Indiana 47460
and
Roy Grimes,[1]
Indiana Division of Fish and Wildlife
LaPorte, Indiana 46350

The need for programs that encourage development and protection of wildlife habitat on private land has long been recognized (Committee On Game Policy 1930). Past private land wildlife management efforts have focused on technical assistance, planting materials, cost-share and lease agreements, and tax incentives (Dumke et al. 1981). The tax incentive concept has been given recent emphasis by creation of programs in Indiana (Russell and Machan 1981), Iowa (Dermand and Herring 1983), Minnesota (Peterson and Madsen 1981), Texas and Wisconsin (Walton 1981).

In September 1979, the Indiana Division of Fish and Wildlife was given responsibility by the state legislature for implementing a broad-based property tax reduction act for wildlife habitat protection (Indiana Code Title 6-1.1-6.5, as amended). This paper summarizes the success of that program from its implementation through 1985.

Wildlife Classification and Property Tax Assessment

Providing property tax incentives to Indiana landowners was not a new concept. In 1921, the state's Classified Forest Act (Indiana Code Title 6-1.1-6, as amended) passed and gave landowners the opportunity to designate timbered tracts as classified forest. Qualifying areas were assessed at $1/ac. Through 1985, 4,821 Indiana landowners had 5,543 tracts totaling 267,000 ac in this forestry program (Indiana Division of Forestry 1985). The classified wildlife habitat act (CWHA) was patterned after the 1921 forest classification act. In the late 1960s, the CWHA was proposed by conservation officials, but it did not receive serious consideration and approval by the state legislature until 1979 (Russell and Machan 1981).

Indiana property tax assessments on land, structures, and legal drainage ditches are conducted by county officials. Only land value is affected by classification. Land assessments are based on soil types, slope and land use. A factor based on soil and land characteristics is multiplied by a base rate of $450/ac to derive a "true cash land value" (TCLV)/ac. This TCLV times the number of ac is then multiplied by 0.33 to derive the assessed land value of a property. Periodic reassessments are overseen by the State Board of Tax Commissioners, with a new Indiana reassessment set for 1987.

Property tax rates are developed by county officials and submitted to the State Board of Tax Commissioners for approval. Tax rates vary by townships within counties and are based on dollar and cents value/$100 assessed valuation. Land entered as classified wildlife habitat is assessed at $1/ac. Depending on local tax rates only a few cents/ac are actually paid by landowners enrolled in the CWHA. The $1/ac does not change with reassessment, but could be changed by legislative authority. Indiana's classified forest program, however, has had land assessed at a constant $1/ac since 1921. Proerty taxes are collected by county governments or municipalities and revenues collected fund their projects. The CWHA does not involve state income taxes.

Requirements for Wildlife Classification

Any parcel of Indiana land can qualify for wildlife classification if it meets certain minimum standards (Table 1).

TABLE 1. Land requirements for entry into Indiana's classified wildlife habitat program.

Requirements
Parcel contains a minimum 15 ac.
Area has less than 10 ac of contiguous woodland. Larger woodland tracts qualify for the classified forest program.
Tract contains trees, shrubs, grasses, or herbaceous vegetation capable of supporting wildlife.
Area has no dwelling or usable building.
No part lies within a licensed shooting preserve.
No grazing or commercial crops (except timber) can be produced on the tract.

Landowners contact district biologists who inspect the property to determine if the parcel qualifies for wildlife classification and answer landowner's questions. Landowners considering the CWHA are encouraged to make a long-term commitment for their classified tracts.

If the landowner decides to proceed with classification, then a registered land surveyor must draw a plat of the tract and develop a legal description. The survey is usually completed using an aerial photograph and the owner's deed description. The local county assessor is also contacted to complete an assessment form of the prospective classified parcel. After that information is secured, the district biologist reviews the forms and returns them to the property owner for recording at the respective county recorder's office.

After proper forms have been recorded, the Division of Fish and Wildlife notifies the county auditor to adjust tax records by assessing the parcel at $1/ac. Taxes are not reduced until the second spring tax installment after classification is completed. Areas designated as classified wildlife habitat annually receive the reduced tax assessment without need for further paperwork. Only if a withdrawal is initiated will the tract be reassessed at the full rate.

Classified landowners can withdraw voluntarily from the program at any time or be taken out of the program because of violations of the basic requirements. Landowners undergoing a withdrawal are required to pay the lesser value of an unearned increment tax or back taxes normally paid on the property. The increment tax is the difference in assessed value/ac on the classified area when it was entered and at the time of withdrawal. Back tax payment is the property taxes normally due on the classified area, plus a 10% penalty/year. The property tax penalty is only computed for a maximum 10 years, i.e. if a tract is withdrawn after 7 years then 7 years back taxes may be due. Withdrawal provisions were designed to protect the classified program from land speculators.

By law, on site inspections of classified tracts occur every 2 years and landowners are provided a minimum of 4 signs for posting on the boundaries of the tract. The signs delineate the area and are printed with a "restricted public use" phrase. All classified tracts remain private property and owners relinquish none of their basic property rights.

The Division of Fish and Wildlife requires classified wildlife habitat owners to complete an annual report concerning property ownership, land use changes and the need for wildlife habitat development assistance.

Wildlife classification does not require that any habitat work be completed, but landowners have access to free technical assistance and monetary assistance is also available through other division programs.

In 1983, an amendment to the classified forest and wildlife acts was passed that permits the transfer of classified tracts between forest and wildlife areas. This allows landowners who have land use changes to maintain maximum classified acreage. District foresters and wildlife biologists handle the necessary paperwork. Landowners are only required to record the transfer form.

Methods

Classified area records for 11 statewide wildlife management districts were compiled from north and south regional office files. The number of parcels and total area from registered land surveyor plats were recorded.

On initial inspections of classified areas, biologists estimate the area of each habitat type and list them on standard forms. Estimates of habitat types are based on planimeter or dot grid measurements from aerial photographs. Total area for each habitat type was recorded and calculated as a percentage of total area.

A classified wildlife questionnaire on survey costs, withdrawals, transfers, landowner attitudes and classified problems was completed by 11 district biologists.

Each classified wildlife landowner is required to annually complete a questionnaire concerning their classified area. One question asked if any wildlife habitat improvement work was completed on their classified tract. Responses were tabulated and listed as a percentage of total responses.

Eleven district biologists were requested to randomly select 10 classified wildlife tracts from their districts. For each tract chosen, biologists secured tax information from county assessors on assessed land value before and after classification. Since tax rates vary by county and township, actual tax savings were computed from tables supplied by the Indiana State Board of Tax Commissioners. The difference in assessed values before and after classification was multiplied by the respective tax rate to compute tax savings/year. All data were analyzed using the Statistical Analysis System (SAS Institute Inc. 1982).

Results

Through 1985, 494 tracts covering 19,165.3 ac had been entered as classified wildlife habitat. Tract size averaged 38.8 ac and 82 of Indiana's 92 counties had ≥ 1 classified tract. Interest in the classified program has varied annually, with 1984 producing the most new areas and acres enrolled (Table 2). Approximately 1,000 potential classified tracts had been inspected through 1985.

TABLE 2. Area entering Indiana's classified wildlife program through 1985.

Year	No. new areas classified	Area (ac) enrolled
1979[a]	3	70.3
1980	82	2769.5
1981	76	2875.4
1982	51	1509.3
1983	86	4028.4
1984	115	4250.6
1985	81	3661.8
Totals	494	19165.3

[a] Program effective September 1979.

Shrublands (33.1%) represent the most common habitat types on statewide classified wildlife areas. Other habitat types on classified tracts are: grass or herbaceous, 22.7%; wetlands, 21.8%; woodland 18.5% and open water, 3.9%. Annual inspection reports from 1985 revealed that classified landowners were completing some form of wildlife habitat management on 53% (N = 249) of their classified tracts.

A stratified random survey of 110 classified tracts yielded a statewide mean (± SD) tax savings of $2.04 ± 0.66/ac and $76.96 ± 36.29/tract based on 1983 property tax rates (Table 3). The north region consistently had more areas and acres enrolled in the classified program than the south region. Part of that difference is simply the larger area and greater number of biologists working in the north region (7 biologists north vs. 4 south). But it was also thought there may be higher tax savings on classified land in the north region. However, the average tax savings/ac was not statistically significant (P = 0.31) between north and south regions. Tax savings/ac was also not significant (P = 0.37) among the 11 districts within the state. There was a wide variation within each district because of the difference in assessments on the various types of land being classified.

TABLE 3. Tax savings/year for Indiana classified wildlife tracts based on 1983 property tax rates.[a]

Area[a]	Savings/ac	Savings/tract
North	$1.00 ± 0.75 (70)	$74.86 ± 42.99 (70)
South	$2.10 ± 0.39 (40)	$81.47 ± 12.15 (40)
Statewide	$2.04 ± 0.66 (110)	$76.96 ± 36.29 (110)

[a] $\bar{x}$ ± SD; N in parenthesis.
[b] North Region = 57 counties; South Region = 35 counties

Eleven withdrawals of classified wildlife areas and 24 transers from the classified forestry program occurred through 1985. District biologists reported an average of 22% (about 1 day/week) of their time was spent working on the CWHA. The classified workload ranged from less than 5% to 40% and was based on district size plus biologist and landowner interest.

Ten of 11 (91%) district biologists indicated landowners entering wildlife classification were doing so because of tax savings. Other reasons given by biologists for landowner entry into the program are (% biologists reporting): Special concern for wildlife (82%), recognition through signs that land has wildlife value (45%), and technical assistance available (27%). Seven of 11 (64%) district biologists also reported the primary reason individuals were not completing classification was the survey cost for the legal description and plat. Survey fees averaged from $50 to $100 according to biologists. The possible payment of back taxes if land is withdrawn (45% of biologists expressed this point) was another concern for landowner hesitation for classification.

Discussion

With a tax incentive program of this type, a certain amount of landowner apprehension was expected. Even with Indiana's 1921 classified forest program, landowner misunderstanding still exists. With the CWHA, twice as many areas have been inspected as have enrolled. In some cases the property does not meet the criteria for the program, but more often, properties do qualify, but landowners do not complete the classification process. Survey costs for property owner legal descriptions and plats and possible withdrawal payment of back taxes were the two most common excuses landowners gave biologists for not completing classification. It seems unlikely that the survey requirements could be dropped completely since both county tax and wildlife officials need some degree of accuracy to locate a classified area and compute acreage entering the program. This is especially important from a tax standpoint, because different types of land are assessed at different levels. The point can also be made that if landowners aren't willing to pay survey costs how serious are they in establishing a long-term classified area. If it is determined to be administratively favorable to increase the number of inspected tracts entering classification, possibly a part-time surveyor could be contracted to prepare a legal description and plats for all statewide classified areas or a landowner incentive could be offered to defray part of the survey fee.

Withdrawal from wildlife classification and possible payment of back taxes is another reason some interested landowners have not entered the program. They believe possible payment of back taxes plus the interest penalty is too severe. Their feelings may be justified, but a minimal withdrawal payment is needed to protect the CWHA from tax abuses. Possibly the law could be amended by reducing the current 10% annual penalty by 1%/year through the tenth year. For example, if a landowner withdraws after 7 years, the maximum penalty would be 7 years back taxes plus 3%/year penalty instead of the current 10%/year. Anytime after 10 years, the maximum owed would be 10 years back taxes with no penalty.

Overall, individuals entering the program appear to have a positive image about it and appear pleased with the recognition given to their land for having wildlife benefits. Annual contact, either by letter or visit has generated requests for assistance with habitat improvement. In fact, one of the most beneficial aspects of wildlife classificatin may be maximizing opportunities for wildlife habitat management on numerous scattered private wildlife tracts around the state. Minimal landowner dissatisfaction can be judged by the relatively few withdrawals that have occurred.

Wetland protection through wildlife classification has been another extremely positive aspect of the program. The amount of wetland area classified (21.8%) is large in comparison to its occurrence as a statewide habitat type. The advantage of a long-term reduced tax rate for wetlands is attracting landowner interest. In Kosciusko County in north central Indiana, biologists secured support of county officials in recognizing wetland values and information on the CWHA was mailed to landowners with their annual tax statements.

The most negative aspect of the CWHA has come from local government officials in 4 counties. Their reluctance to process classified wildlife paperwork may be based on personal feelings on the extra work it creates or the fact it reduces the local property tax base. In those areas, it has required closer monitoring on the part of landowners and district biologists to ensure proper entry of land to classified wildlife status.

One other administration problem deals with reinspections. The 1979 CWHA requires onsite inspections every 2 years, while the 1921 classified forest law requires them every 5 years. The reason the 2 year interval for wildlife resinspections was developed in the legislature is not known. Few problems or violations of classified wildlife requirements have been discovered during reinspections. As the number of wildlife tracts increase, the 2 year resinspection will require greater manpower needs. The current law should be amended to increase the onsite reinspection interval.

Recommendations

Even though the CWHA has been accepted by many landowners, certain aspects of the program could change to reflect improved landowner and administration interests. Those recommendations are:

1. Study possibilities to minimize landowner survey costs.
2. Amend the law by reducing the 10% annual penalty by 1%/year through the tenth year.
3. Change the law by increasing the reinspection interval to a 4 or 5 year period.

Future Needs

Indiana's wildlife management efforts on private land hold more promise because of the CWHA. The concept of recognizing landowners as joint custodians of our wildlife resources and compensating them through reduced tax benefits has merit. The future of Indiana's CWHA may depend on the ability of the program to parallel the dynamic changes of land ownership. The following suggestions are offered as consideration for future program direction:

1. A questionnaire should be developed to learn more about existing classified landowner interests and needs.
2. An award for classified landowners should be created. A certificate could be presented for the years a classified tract has been in the program and/or recognition given to landowners doing an outstanding job of wildlife habitat management on a classified area. This recognition may help encourage other private landowners to enter the program and protect wildlife habitat.
3. Conduct a wildlife inventory to educate landowners about the diversity and abundance of wildlife occurring on classified tracts. This inventory could be available to classified owners at their request and should be designed to include landowner participation.
4. If classified landowner interest exists, special workshops could be held periodically to discuss species life histories and habitat management techniques. This short-course would be another way to encourage private landowner interest in wildlife habitat protection.

Acknowledgments

The assistance of M.E. Bennett, J.S. Castrale, L. Granderson, E.M. Guljas, G.L. Langell, R.L. Porch, R.E. Rolley, J. Russell, J. Scheidler, J. Thompson, A.F. Van Hoey, D. Whittlesey, and M.D. Zimmerman was appreciated. We also thank D. Major and R.J. Showalter for their support and encouragement.

Literature Cited

1. Committee On Game Policy. 1930. American game policy. Trans. Game Conf. 17:284-309.
2. Dermand, S. and K. Herring. 1983. The slough bill. Iowa Conservationist 42 (12):4-7.
3. Dumke, R.T., G.V. Burger, and J.R. March, eds. 1981. Wildlife management on private lands. LaCrosse Printing Co., Inc., LaCrosse, Wisconsin. 576pp.
4. Indiana Division of Forestry. 1985. Annual report. Indiana Dep. Nat. Resour., Indianapolis.
5. Peterson, C. and C.R. Madsen. 1981. Property tax credits to preserve wetlands and native prairie. Trans. North Am. Wildl. and Nat. Resour. Conf. 46:125-129.
6. Russell, J. and W. Machan. 1981. Indiana's classified wildlife habitat act. Pages 527-531 *in* R.T. Dumke, G.V. Burger, and J.R. March, eds. Wildlife management on private lands. LaCrosse Printing Co., Inc., LaCrosse, Wisconsin. 576pp.
7. SAS Institute Inc. 1982. User's guide: Basic 1982 edition. SAS Institute Inc., Cary, North Carolina. 923pp.
8. Walton, M.T. 1981. Wildlife habitat preservation programs. Pages 193-208 *in* R.T. Dumke, G.V. Burger, and J.R. March, eds. Wildlife management on private lands. LaCrosse Printing Co., Inc., LaCrosse, Wisconsin. 576pp.

Note

Present address: David Howell, R.R. 1, Box 88A, Stendal, Indiana 47585
Present address: Ray Grimes, Patoka Reservoir, R.R. 1, Birdseye, Indiana 47513

Abundance and Characteristics of Northern Indiana Wetlands

Robert E. Rolley
Indiana Division of Fish and Wildlife
300 W. First Street
Bloomington, Indiana 47401
and
Jimmy F. New
Indiana Division of Fish and Wildlife
5344 S. Hupp Road
LaPorte, Indiana 46350

Introduction

Fresh water wetlands are among the most productive habitats on earth. Wetlands are essential habitat for many species of waterfowl, furbearers, nongame birds and mammals, fish, mollusks, herptiles, and plants. Other values of wetlands include timber production, flood control, water quality improvement, erosion control, and recreation (Tiner 1984).

An estimated 178,000 ha of inland wetlands are lost nationally each year, primarily due to agricultural development. Approximately 54% of the original 81,000,000 ha of wetlands in the 48 contiguous states had been drained or filled by the mid-1970's (Tiner 1984).

Information on the abundance and characteristics of wetlands is needed to guide wetland conservation efforts. This study was undertaken to provide preliminary information on wetlands in northern Indiana as part of an ongoing statewide wetland inventory.

Methods

The size and classification of wetlands were determined from wetland maps and interpreted aerial photographs, enlarged to a scale of 1:24,000, that were prepared by the National Wetlands Inventory, U.S. Fish and Wildlife Service. Color-infrared aerial photographs were taken during May and June 1981-84. Wetland maps and interpreted photo-enlargements were available for the northern third of the state. The study area was divided into two regions, the Northern Indiana Wetland Region (NIWR) and the Kankakee and Wabash River Watersheds (KWRW), based on a subjective assessment of wetland density (Figure 1).

Wetlands were classified according to Cowardin et al. (1979). The Lacustrine system includes large permanently flooded lakes, reservoirs, and smaller basins that are greater than 2 meters deep. Palustrine wetlands are small and/or shallow areas, usually dominated by hydrophytic vegetation, frequently referred to as marshes, swamps, bogs, or fens. The Riverine system includes wetlands that are contained within a channel that at least periodically contains flowing water.

Water regime modifiers describe the duration and frequency of flooding which partially influences the plant and animal communities of wetlands. Temporarily flooded wetlands have surface water for only short periods of time during the growing season and ground water is usually well below the surface. Ground water is usually at or near the surface in saturated wetlands. Seasonally flooded wetlands have surface water for extended periods early in the growing season but usually become dry by the end of the growing season. Semipermanently flooded sites have surface water throughout the growing season in most years, intermittently exposed areas have surface water in all but the driest years, and permanently flooded wetlands have surface water in all years. Intermittently flooded wetlands usually have exposed substrates but surface water may be present for

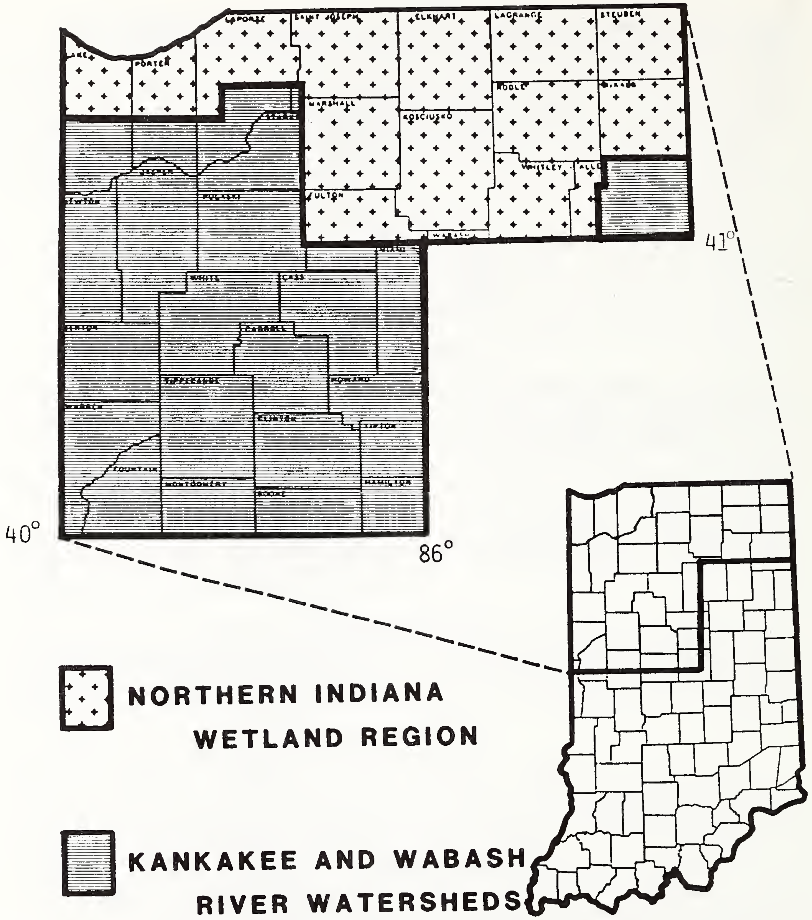


Figure 1. Location of northern Indiana study area.

variable periods not related to season flooding. Artificially flooded wetlands are those where the duration and timing of flooding are controlled by man with pumps, siphons, dikes, or dams.

We used a stratified random sample of sections (2.59 sq. km) to estimate the area and abundance of wetlands. The sampling scheme was modified from that described by Brewster et al. (1976) and Heitmeyer (1980). One section was randomly selected from each of 333 townships in northern Indiana. The number of wetlands in each section and their classification were recorded. The area of every wetland in the sample quadrats was measured with a Numonics digitizer. Very narrow wetlands, that were mapped with lines instead of enclosed polygons, were assumed to be 6.1 m wide for area calculations.

The mean (± SE) number and ha of wetlands in the sample quadrats were expanded to estimate the number and ha of surface area of wetlands in each region. Chi-square tests of independence were used to examine regional differences in the distribution of wetland classifications. Regional differences in wetland size were examined with t-tests.

Wetland areas were log-transformed because size distributions differed significantly from normality ($P \leq 0.01$).

We used the terminology of Cowardin (1982) to differentiate between wetlands (areas of homogeneous hydrologic, edaphic, and biological characteristics) and wetland basin (land feature capable of holding water). A wetland basin may contain one or more wetlands.

Results

A total of 2,329 wetland basins were present within the 333 sampled quadrats. Eighty-four percent of the wetland basins were homogeneous areas containing a single wetland. The remaining 16% were heterogeneous areas with two or more wetlands per basin. These heterogeneous basins contained an average of 3.0 wetlands/basin.

Sampled sections within the NIWR contained a mean of 10.8 ± 0.7 wetland basins and 23.3 ± 2.5 ha of wetlands. Extrapolation of these estimates to the entire 11,932 km^2 region resulted in an estimated 49,603 ± 3,032 wetland basins that covered 107,145 ± 11,681 ha. Within the KWRW, sampled quadrats contained an average of 4.5 ± 0.3 wetland basins and 10.0 ± 1.1 ha of wetlands. These estimates expand to 35,463 ± 2,600 basins and 78,722 ± 8,812 ha of wetlands within the 20,479 km^2 KWRW. In the northern third of Indiana, we estimate that there were 85,066 ± 3,939 wetland basins and 185,867 ± 17,292 ha of wetlands.

Palustrine wetlands comprised 96% of the wetlands and 78% of the wetland surface area in northern Indiana (Table 1). Only 1% of the wetlands were lacustrine, but because of their relative large area ($\underline{\bar{x}} = 26.6$ ha), lacustrine wetlands comprised 19% of the wetland surface area. Three percent of wetlands were riverine and these accounted for 3% of the wetland surface area.

TABLE 1. Estimated number and area (ha) of wetlands of each wetland system in northern Indiana. Standard errors of the estimates are in parentheses.

Wetland system	Northern Indiana Wetland Region	Kankakee & Wabash River Watersheds	Total
N wetlands			
Lacustrine	828	473	1,301
	(175)	(140)	(225)
Palustrine	63,666	44,487	108,152
	(3,767)	(3,272)	(4,927)
Riverine	691	2,799	3,490
	(159)	(382)	(385)
Area of wetland			
Lacustrine	21,483	13,131	34,613
	(2,542)	(1,694)	(3,473)
Palustrine	84,430	60,529	144,960
	(9,260)	(6,842)	(13,557)
Riverine	1,243	5,062	6,305
	(297)	(793)	(843)

The distribution of wetland systems differed slightly but significantly between the two regions ($\underline{\chi}^2 = 59.7$, df = 2, $\underline{P} < 0.001$). Riverine system wetlands composed 6% of wetlands in the KWRW but constituted only 1% of the wetlands in the Northern Indiana Wetland Area. Palustrine wetlands composed 93% and 98% of the wetlands in the KWRW and NIWR, respectively.

Seven wetland classes were represented in the sampled quadrats. Unconsolidated bottom, the predominant class for both lacustrine and riverine system wetlands, formed 99% of the wetland surface area for lacustrine system wetlands and 98% for riverine system wetlands. The remaining area of lacustrine wetlands was classified as unconsolidated shore. The class streambed comprised 1% of the riverine surface area, as did the class unconsolidated shore.

The most frequent classes of palustrine wetlands were forested, emergent, and scrub-shrub wetlands (Table 2). In the entire study area, 52% of the palustrine surface area was composed of forested wetlands, 32% was emergent wetlands, and 10% was scrub-shrub wetlands.

TABLE 2. Estimated area (ha) of wetland classes in northern Indiana. Standard errors of the estimate are in parentheses.

Wetland system and class	Northern Indiana Wetland Region	Kankakee & Wabash River Watersheds	Total
Lacustrine			
Unconsolidated bottom	21,303	13,131	34,434
	(2,552)	(1,694)	(3,480)
Unconsolidated shore	180	0	180
	(401)		(416)
Palustrine			
Aquatic bed	388	291	679
	(140)	(129)	(192)
Emergent	30,876	14,933	45,809
	(3,516)	(1,858)	(4,459)
Forested	37,968	37,794	75,770
	(4,279)	(4,360)	(7,209)
Scrub-shrub	10,511	2,948	13,460
	(1,323)	(511)	(1,477)
Unconsolidated bottom	4,677	4,564	9,241
	(683)	(702)	(1,081)
Riverine			
Streambed	0	39	39
		(53)	(52)
Unconsolidated bottom	1,243	4,960	6,203
	(297)	(782)	(834)
Unconsolidated shore	0	62	62
		(67)	(66)

The distribution of palustrine wetland classes was significantly different between regions ($\chi^2 = 27.2$, df = 5, $P < 0.001$). The forested class made up 62% of the palustrine wetland surface area in the KWRW, whereas it composed 45% of the surface area in the NIWR. Emergent and scrub-shrub classes comprised 37% and 12%, respectively, of the wetland surface area in the NIWR as compared to 25% and 5% in the KWRW.

The majority of the surface area of lacustrine wetlands has surface water present throughout the year in virtually all years. Eighty-seven percent of the lacustrine surface area in the sampled quadrats was classified as permanently flooded, 8% was mapped as intermittently exposed/permanently flooded, and 4% was mapped as intermittently exposed (Table 3). Water regimes seasonal, semipermanent, intermittently flooded, and artificial were combined with water regime intermittently exposed/permanent for analysis of the regional distribution of water regimes for lacustrine wetlands because of the low expected frequencies for these water regimes. There was no significant difference in the distribution of water regimes between the two regions ($\chi^2 = 4.1$, df = 2, $P = 0.13$).

TABLE 3. Estimated area (ha) of wetlands with each water regime in northern Indiana. Standard errors of the estimates are in parentheses.

Wetland system and water regime	Northern Indiana Wetland Region	Kankakee & Wabash River Watersheds	Total
Lacustrine			
Seasonal	176 (396)	0	176 (411)
Semipermanent	34 (175)	0	34 (182)
Intermittently exposed	662 (762)	645 (823)	1,306 (1,107)
Permanent	17,843 (2,677)	12,486 (1,807)	30,330 (3,587)
Intermittently flooded	4 (62)	0	4 (64)
Artificial	99 (297)	0	99 (308)
Intermittently exposed/permanent	2,664 (1,479)	0	2,664 (1,561)
Palustrine			
Temporary	10,376 (1,309)	32,667 (3,800)	43,044 (4,205)
Saturated	5,226 (744)	127 (84)	5,353 (709)
Seasonal	44,106 (4,936)	19,647 (2,376)	63,754 (6,107)
Semipermanent	5,817 (810)	3,002 (518)	8,819 (1,042)
Intermittently exposed	1,849 (352)	1,912 (382)	3,761 (550)
Permanent	1,613 (322)	1,646 (347)	3,259 (498)
Artificial	25 (34)	0	25 (35)
Saturated/semipermanent/ seasonal	11,254 (1,404)	1,271 (295)	12,526 (1,389)
Intermittently exposed/permanent	186 (94)	157 (93)	343 (133)
Unknown	3,977 (603)	97 (73)	4,073 (582)
Riverine			
Seasonal	0	62 (67)	62 (66)
Semipermanent	0	20 (38)	20 (37)
Permanent	1,194 (290)	4,860 (770)	6,053 (820)
Saturated/semipermanent/ Seasonal	0	19 (37)	19 (37)
Intermittently exposed/permanent	49 (55)	101 (86)	150 (103)

The distributions of water regimes for palustrine wetlands differed markedly between regions (χ^2 = 758, dr = 9, P < 0.001). Over 53% of the palustrine surface area in the KWRW was classified as temporarily flooded, but only 12% of the palustrine area in the NIWR was so classified. Saturated and seasonally flooded wetlands were proportionally more common in the NIWR. Water regime could not be determined from the aerial photography for 5% of the palustrine surface area in the sampled sections of the

NIWR. Less than 1% of the palustrine area in the KWRW was mapped with a water regime of unknown. Within the entire study are, 45% of the palustrine area was seasonally flooded, 28% was temporarily flooded, 6% was semipermanently flooded, 4% was saturated, 2% was permanently flooded, and 9% was mapped as saturated/semipermanent/seasonal (Table 3).

In the northern third of Indiana, 96% of the riverine surface area was permanently flooded, and 2% was intermittently exposed/permanent. Less than 2% of the riverine area was classified with water regimes of either seasonally flooded, semipermanently flooded, or saturated/semipermanent/seasonal. Water regimes seasonal and saturated/semipermanent/seasonal were combined with water regime semipermanent in order to test distribution of regimes between regions. The distribution of water regimes for riverine wetlands did not differ significantly between the NIWR and the KWRW ($\chi^2 = 2.3$, df = 2, $P = 0.31$).

The classification of mapped wetlands indicated whether the wetland was man-made or modified by man. Lacustrine wetlands in the NIWR were predominantly non-modified natural wetlands, whereas those in the KWRW were mostly diked or impounded (Table 4). This difference was significant ($\chi^2 = 16.8$, df = 2, $P < 0.001$).

Table 4. Estimated area (ha) of natural wetlands and wetlands with man-made modifications in northern Indiana. Standard errors of the estimates are in parentheses.

Wetland system and modification	Northern Indiana Wetland Region	Kankakee & Wabash River Watersheds	Total
Lacustrine			
Not modified	19,440	1,589	21,029
	(2,636)	(1,253)	(3,520)
Diked/impounded	1,119	11,328	12,447
	(983)	(1,959)	(3,037)
Excavated	923	214	1,138
	(896)	(481)	(1,035)
Palustrine			
Not modified	73,479	56,165	129,645
	(8,086)	(6,366)	(12,152)
Partially drained/ ditched	8,975	1,543	10,518
	(1,156)	(333)	(1,201)
Farmed	0	36	36
		(44)	(42)
Diked/impounded	380	1,090	1,470
	(138)	(269)	(300)
Excavated	1,596	1,695	3,291
	(320)	(343)	(502)
Riverine			
Not modified	353	3,872	4,225
	(151)	(658)	(645)
Excavated	890	1,190	2,080
	(247)	(316)	(417)

While over 87% of the palustrine surface area in both regions of the study area was not modified, the distributions of modifications to palustrine wetlands differed between regions ($\chi^2 = 42.8$, df = 4, $P < 0.001$). Eleven percent of the palustrine surface area in the NIWR had been partially drained or ditched but only 3% had been partially drained or ditched in the KWRW. Seventy-two percent of the surface area of riverine wetlands in the NIWR was excavated vs. 23% in the KWRW. The frequency of excavated riverine wetlands was not significantly different between regions ($\chi^2 = 1.8$, df = 1, $P = 0.17$).

Lacustrine wetlands in northern Indiana were generally large, with 53% exceeding 10.0 ha in area (Table 5). Wetlands larger than 10.0 ha comprised 94% of the lacustrine surface area. The lacustrine system did include some smaller wetlands; 28% were 5.0 ha or smaller in area. Sizes of lacustrine wetlands did not differ significantly between the two regions of the study area (t = 0.40, df = 34, P = 0.69).

TABLE 5. Estimated number and area (ha) of wetlands in northern Indiana in various size categories. Standard errors of the estimates are in parentheses.

Wetland system and size category (ha)	N wetlands	Area of wetland)
Lacustrine		
≤0.2	113 (64)	12 (108)
0.3-0.5	35 (35)	11 (102)
0.6-1.0	35 (35)	30 (170)
1.1-5.0	172 (79)	438 (647)
5.1-10.0	256 (97)	1,615 (1,228)
10.1-15.0	103 (61)	1,301 (1,109)
>15.0	586 (148)	31,196 (3,572)
Palustrine		
≤0.2	32,092 (1,720)	2,921 (463)
0.3-0.5	26,624 (1,484)	8,492 (1,011)
0.6-1.0	16,703 (1,046)	11,949 (1,336)
1.1-5.0	26,610 (1,483)	58,924 (5,664)
5.1-10.0	4,246 (431)	29,008 (2,914)
10.1-15.0	1,072 (202)	13,184 (1,451)
>15.0	802 (174)	20,480 (2,128)
Riverine		
≤0.2	424 (128)	44 (55)
0.3-0.5	577 (150)	192 (117)
0.6-1.0	1,079 (208)	760 (238)
1.1-5.0	1,139 (212)	1,630 (362)
5.1-10.0	78 (55)	616 (212)
10.1-15.0	78 (55)	912 (263)
>15.0	113 (66)	2,150 (425)

Over 67% of palustrine wetlands in both regions were 1.0 ha or smaller in size. However, most of the palustrine surface area was composed of relatively few large wetlands. Wetlands larger than 1.0 ha accounted for 84% of the palustrine surface area. Palustrine wetlands in the NIWR were slightly smaller in size than those in the KWRW (t = 2.46; df = 2,963; P = 0.01). Thirty-two percent of palustrine wetlands in the NIWR were ≤ 0.2 ha in size compared to 26% in the KWRW.

Riverine wetlands within the sampled sections rarely exceeded 5.0 ha in size. The median size of riverine wetlands in the NIWR and the KWRW was 1.0 and 0.7 ha, respectively. The size of riverine wetlands did not differ significantly between regions of the study area (t = 0.14, df = 87, P = 0.89).

Discussion

The density of wetlands in the NIWR was approximately twice as high as in the KIRW. Palustrine wetlands dominated by emergent scrub-shrub vegetation were more common in the NIWR, whereas a greater proportion of the palustrine surface area in the KWRW was characterized as forested. Palustrine wetlands in the KWRW tended to be flooded for shorter durations than those in the NIWR. Drainage rates of palustrine wetlands appear to be higher in the NIWR. The majority of lacustrine wetlands in the NIWR were natural in origin, while those in the KWRW were primarily man-made.

This examination of the abundance and characteristics of northern Indiana wetlands was designed to provide preliminary information needed to guide future wetland conservation efforts. These estimates of wetland abundance can serve as a baseline against which future wetland losses can be assessed. Such comparisons are important for evaluation of the effectiveness of wetland conservation measures. Furthermore, this information on the abundance of wetland habitats can serve as the basis for future research to quantify the abundance and distribution of wildlife species that are dependent on wetland habitats.

Acknowledgments

We greatly appreciate the efforts of the U.S. Fish and Wildlife Service in preparation of wetland maps. G. Craig assisted with wetland digitizing. C.A. Albright, R.D. Feldt, D.C. Hudak, and T.J. Moser reviewed earlier drafts of this manuscript and provided many helpful comments and suggestions.

Literature Cited

Brewster, W.G., J.M. Gates, and L.D. Flake. 1976. Breeding waterfowl populations and their distribution in South Dakota. J. Wildl. Manage. 40:50-59.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetland and deepwater habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79/31. 103pp.

Cowardin, L.M. 1982. Some conceptual and semantic problems in wetland classification and inventory. Wildl. Soc. Bull. 10:57-60.

Heitmeyer, M.E. 1980. Characteristics of wetland habitats and waterfowl populations in Oklahoma. M.S. thesis. Oklahoma State University, Stillwater. 263pp.

Tiner, R.W., Jr. 1984. Wetlands of the United States: current status and recent trends. U.S. Fish and Wildlife Service, National Wetlands Inventory. 59pp.

A Comparison of Surface Vegetation on Unreclaimed 1949 Indiana Coal Spoilbanks in 1964 and 1981

JOHN RICHARD SCHROCK
Division of Biological Sciences
Emporia State University
Emporia, Kansas 66801
AND
JACK R. MUNSEE
Department of Life Science
Indiana State University
Terre Haute, Indiana 47809

Introduction

In 1964, Munsee (9) studied the ecology of ants on relatively barren unreclaimed Indiana spoil banks originally deposited in 1949-51. In 1981, Schrock (12) repeated the methodology at the same 21 sites, now mostly revegetated. While the primary focus of both studies was the surface active insect populations (10), samplings of both the soil (14) and vegetation at each site were used in analyses to explain the distribution of selected insects. Of these major factors studied by Munsee and Schrock—soils, herbaceous vegetation, trees, and insects—this paper summarizes the surface vegetation data.

Previous studies (1, 11, 17) studying successional changes at one point in time by comparing a series of multi-aged spoil banks assume a uniformity of both spoils and microclimate, but themselves often reveal adjacent but highly contrasting sites of equal mining age.

The Munsee and Schrock studies, 17-years apart, constitute one of the few real-time comparisons of changes on humid Midwestern spoil banks over a substantial period of time, and on which a large amount of data has been amassed (9, 10, 12, 13, 14, 15).

Methods

In 1964, Munsee selected an ecological study area in the old Sunspot Mines, strip-mines south of Centenary in Vermillion County, Indiana, in Township 14N, Section 24 (10). Physical site descriptions are detailed in Schrock & Munsee (14). The spoilbanks resulted from surface coal mining by Ayrshire Colleries from 1949 to 1951. Ayrshire sold about 300 acres of the spoilbanks to the Clinton Chapter of the Isaac Walton League. Protection provided by the League and the remoteness of the research site prevented disturbance of the research site over the past 41 years. All seed dispersal is presumed natural.

Twenty-one research sites, 19 on mined spoilbanks and two in adjacent unmined area, were selected in 1964 to provide an assortment of exposures and slopes (9, 14). The size and shape of plots varied with topography (Figure 1). Plots were oriented to avoid problematic areas. A variety of tops, slopes and bases of ridges were sampled. Detailed 1964 field notes and the rough and varied terrain permitted reestablishment of the same plots in 1981.

Sites were designated by letters, beginning with "Site A" in the south end of the area and working north along the mined ridges and west to east when sites cut across ridges. "Site A" was an unmined but previously cultivated site; "Site W" was an unmined wooded site south of the mined area. Therefore, tabular data are presented in the order "W, A, B, C, D. . .T."

Because of the wide variety of plant forms on the sites and due to the rugged terrain, Munsee chose a modified point-contact method to describe the plant community,

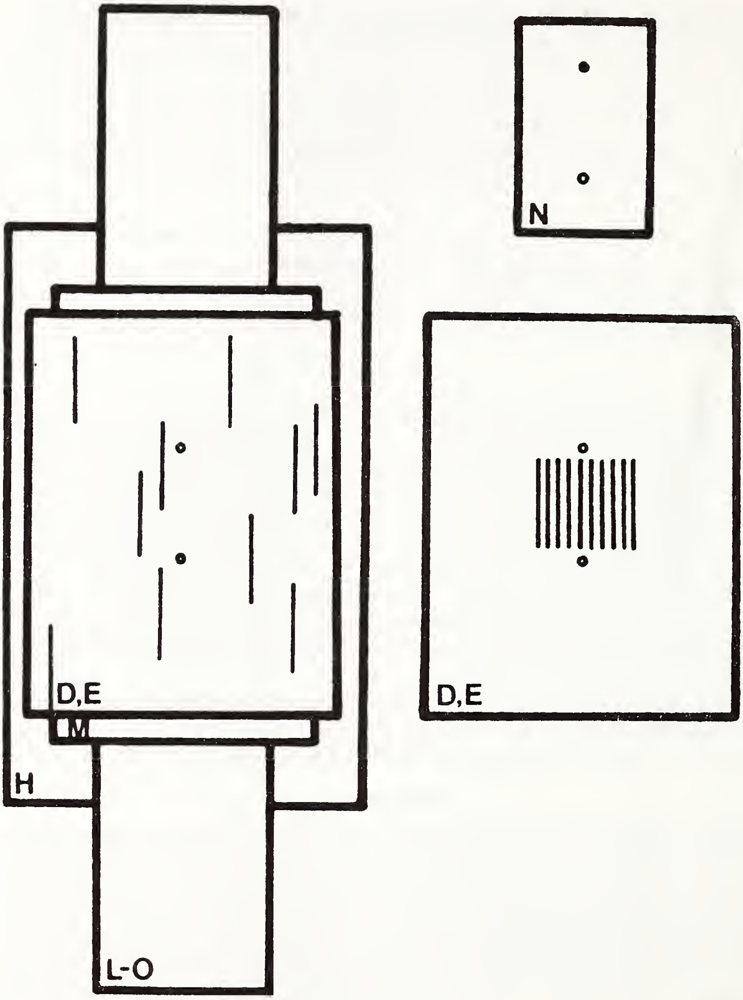


FIGURE 1. Variation in size of vegetation plots. The change in the point-contact sampling pattern is represented by the ten random lines (D, E left) used in 1964 and the central grid of ten lines spaced 30.5 cm apart in 1981 (D, E right).

and this method was also used in 1981. However, while most procedures were the same, there were some differences in the sampling pattern and in the equipment used in these two studies.

Working alone on the barren spoils in 1964, Munsee needed a point-frame that could be set up and operated by one man. He used two 1.8 meter (six foot) 1.6 cm (5/8″)-diameter metal rods to establish the ends of the point frame. A metal cross-bar was welded one foot from the sharpened bottom end. This permitted the rod to be easily driven into the ground and guaranteed the top would extend to a standard height. Ringstand clamps fitted with thumbscrews were fastened to the top end of the rods. This anchored the ends of a clothesline that spanned the 3.27 meter (10′ 9″) between the rods. The rods were reinforced with guy wires and the clamps were adjusted so the line was taut.

Stretched between the rods, the line was divided by ten marks at 30.48 cm. (one foot) intervals. At each of these points, Munsee fastened a plastic draw-drape pulley. A 28 gram (five ounce) carpenter's plumb was attached to nylon fish line and suspended from each consecutive pulley to define the line of point-contact. At each site in 1964 and again in 1981, the plumb line was dropped ten times along each of ten lines for a total of 100 plumb line drops.

In use, the plumb line was lowered slowly from each consecutive pulley. Tallies were made as follows:

1. One tally was made each time the point of the plumb touched a live plant part. Since heavy herbaceous cover resulted in many hits per descent, there was no limit to this tally.
2. Litter was considered any dead and prostrate plant material contacted by the point of the plumb as it reached ground level and therefore there was a limit of 100.
3. Dead parts of live plants and live plants were tallied by plant and not as litter.
4. Bareground was counted when the ground surface contacted by the plumb was stone, clay or any other inorganic material. Again 100 was the limit.

These tally procedures were used uniformly in 1964 and 1981.

The frame apparatus in 1981 was built with different materials. Instead of metal rods and a clothesline, the frame was constructed of wooden boards as shown on site E in Figure 2. The height of the poles and the spacing of the points along the "line" board were identical to the 1964 dimensions. Notches rather than pulleys defined the lowering of the plumb line. This frame required two persons to move but otherwise was much more rapidly set up. The change in frame design is presumed to make no difference in tally results.

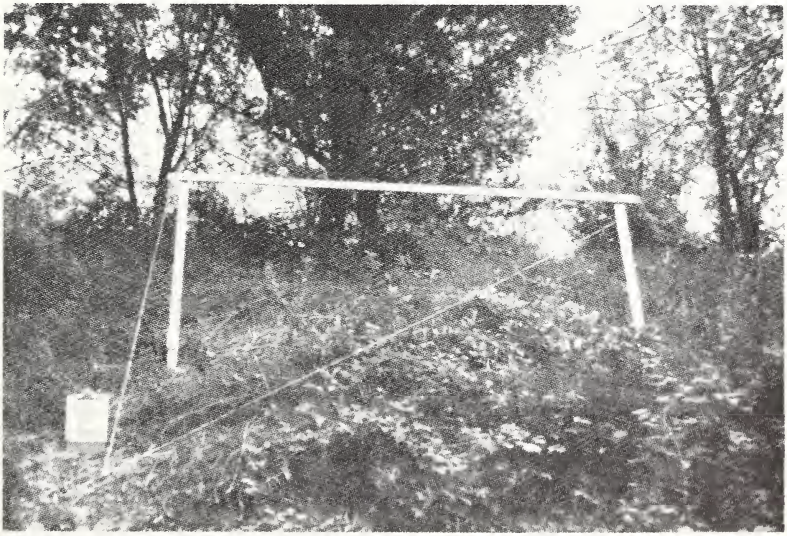


FIGURE 2. View facing east at research site E in 1981. The wooden plant frame is in place over heavy growth of *Melilotus*.

In 1964, the frame was set up ten times at each research site, the position of ten "plots" at each site was determined by a random numbers table. Since many of the mined sites were sparsely vegetated, this method sampled from a wide area around the pitfalls. In 1981, all but D site were well vegetated. In addition, the 1964 "random plots" could not be located again. Since vegetation on the sites was heterogeneous and clumped, two random samples even at the same point in time would show different results. Since replication was impossible, the 1981 vegetation "plots" were set in a 3.048 meter (10-foot) square grid centered on the pitfall traps. This difference in sampling is illustrated in Figure 1.

It is realized that this compact grid decreases the chances of encountering plants sparsely distributed at the site. Bushy or clumped plants in the 1981 grid are likely to be intercepted by several of the lines spaced only 30.5 cm. (one foot) apart. However, two benefits are gained: 1) in denser vegetation, it is likely that the vegetation within 1 to 3 meters will influence the ant sample more than the plants chosen randomly 10 or more meters away, and 2) since the trapsites are relocatable, this vegetation survey can also be repeated in any future follow-up to this study. In addition, this plant survey was originally designed as and remains an examination of factors influencing insect populations on stripmines.

In 1964, Munsee identified common plants in the field. Difficult material was collected and identified in the laboratory. When plants were in the seedling stage, their identity was determined by referring to nearby plants believed to be of the same genus or species. Where possible, identical plants were collected off-site and placed in a plant press. When dried and identified, these were mounted on herbarium paper and labelled. Voucher specimens of both herbaceous specimens and tree leaves were placed in the Indiana State University Herbarium. Munsee's voucher specimens were examined prior to field work in 1981. Specimens collected in 1981 were also dried, mounted, labelled, and deposited in the I.S.U. Herbarium.

Sweet clover, very common in both 1964 and 1981, could be identified to species (i.e., *Melilotus alba* Desr. and *M. officianalis* (L)Lam.) when flowering. Many plots contained a mixture of the two species and since many non-flowering stems were intermixed, only the genus was tallied.

The 1964 plant tallies were conducted over many weeks between servicing of the pitfall traps. Considering that vegetation was sparse, this probably produced little disturbance to both the vegetation and the insect samples. By 1981, the vegetation was dense enough that the process of tallying plants would trample much of the vegetation and distort the insect samples. Therefore, plant tallies were conducted during the last two weeks of the study to minimize this disturbance. Since there is a gradual change throughout the seasons, this variation in tally date, plus overall variation in weather between the two years, should be borne in mind when interpreting the results.

Munsee based his determinations on the revision of Gray's manual by Fernald (6) and on Deam's *Grasses of Indiana* (5). Schrock's determinations were mostly from Gleason and Cronquist (7) and with substantial help on difficult species from Ralph Brooks of the Kansas State Biological Survey.

At each site, the plant frame was set up ten times and using the modified point-contact system described above, this provided ten samples of the vegetation at each site. Frequency of a plant species was defined as the number of linear plots in which the species was encountered at least once, divided by ten. Therefore, if a plant was sparse but very bushy, it would be encountered only on one or two plots and have a low frequency although it might have a high number of point-contact hits due to its dense foliage.

In 1964, Munsee also calculated a relative frequency, a relative density, and a relative dominance for plants at each site and summed them for an importance value for each species (9). However, only the real counts and frequencies were used for the 1964-1981 comparisons for the following reasons:

1. The "plot size" was identical in 1981 and effectively so in 1964, reducing the need to convert to proportions to compensate for different sizes of sample areas.
2. Actual plant hits may directly reflect both biomass and sun-light interception and no longer reflect this when reduced to proportions.
3. The ecological value of an abstract "importance value" constructed from precisely one-third frequency, one-third density, and one-third relative dominance is difficult to show in spite of its use in forest community studies beginning with Curtis and McIntosh (3).

Because of shortcomings described by Chambers (2), standard diversity indices were not used in comparing the vegetation. To describe the complex patterns of similarity between sites, a cluster analysis was performed using each site as a case. For this task, BMDP statistical program P2M was used as modified to run on the Kansas University Computing Center Honeywell DPS-3/E.

Dendrograms were constructed to compare sites with the distance between two sets of vegetation data defined as the chi-square test of equality of the two sets of frequencies. The computer program begins by comparing each pair of cases and using this chi-square test, joins the closest two cases. When two cases are joined, a new centroid is formed by averaging each variable. In the next round of searching for the shortest distance, this centroid is compared with other candidates for membership to the next larger cluster. The number of cases (or pseudo-cases) is reduced by one at each step until all are clustered. The freely rotating cluster dendrograms are then ordered into a successional series by pulling unrecovered site D to one side and unmined forest site W to the opposite side.

Cluster analyses were performed for the 1964 and 1981 sites separately, and for all of these sites taken together. The methodology described above was applied to plant hits, plant frequencies, and plant occurrence. Plant occurrence was based on a data grid of ones and zeros reflecting whether the plant species occurred at the site or not.

Results

Percent bareground in 1981 is greatly reduced at all sites except site D (Figure 3). Ordered from 100% bareground to no bareground in 1964, only E, H, P, and F have substantial bare surfaces in 1981. Based on this same ordering system, 1981 sites have generally increased plant production as represented by hits using the modified point-contact system (Figure 4). The *Melilotus* fraction has increased on those sites with remaining bareground (E, H, P, and F) and at sites Q and N. In other cases, it is either reduced or absent. Slight decreases in plant hits occurred at R, A, and barren site D.

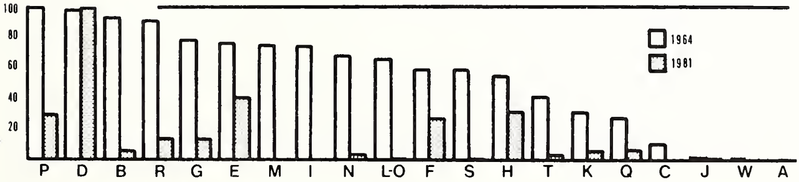


FIGURE 3. Changes in percent bareground at each of 20 research sites between 1964 and 1981.

Table 1 shows that *Melilotus* dominated the 1964 sites along with *Aster*, mustard, and ragweed (*Ambrosia*) making a distant showing. By 1981 (Table 2), *Aster* and *Melilotus* are reduced, ragweed is nearly absent and goldenrod (*Solidago*), blackberry (*Rubus*), Queen Anne's lace (*Daucus carota*), and poison ivy (*Rhus radicans*) abound. Dogwood

TABLE 1. Bareground, litter and plant hits recorded for 20 research sites in 1964. Numbers represent interceptions of each species during a total of 100 plumb line drops. Ten drops were made along each of ten randomly determined lines at each site.

	W	A	B	C	D	E	F	G	H	I	J	K	L-O	M	N	P	Q	R	S	T
Bareground	2	1	93	11	98	77	60	78	56	75	3	33	66	75	68	100	29	91	60	42
Litter	89	96	13	89	—	33	59	23	49	31	97	70	58	29	44	—	72	18	63	59
Ambrosia sp.	—	3	14	17	—	7	5	—	—	9	43	1	78	—	1	—	34	—	12	15
Apocynum sp.	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—
Aristida oligantha	—	—	11	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	6	—
Asclepias syriaca	—	—	—	6	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Aster spp.	—	—	—	1	—	31	1	1	2	6	—	4	4	1	—	—	—	3	4	11
Atrichum angustatum	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bromus commutatus	—	—	—	7	—	—	—	—	20	—	—	—	7	—	—	—	—	—	—	—
Campsis radicans	—	—	—	—	—	—	—	—	121	—	—	—	—	—	—	—	—	—	—	—
Carex spp.	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Celastrus sp.	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chenopodium album	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	—	—	—
Chenopodium sp.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Convolvulus sepium	—	—	—	—	—	—	—	—	—	—	—	31	4	—	—	—	5	—	1	—
Cornus spp.	2	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Danthonia spicata	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Daucus carota	—	2	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Desmodium sp.	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Echinochloa crusgalli	—	—	—	—	—	—	—	—	—	—	—	—	12	—	—	—	2	—	—	—
Eupatorium altissimum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Fraxinus sp.	2	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
Ipomea pandurata	—	—	—	—	—	—	—	—	14	—	—	—	—	—	—	—	—	—	—	—

Lactuca spp.	—	2	—	—	—	1	—	—	—	10	—	—	1	1	—	—	1	—	1	3
Lepidium densiflorum		—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	1	—
Lepidium sp.	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
Lespediza spp.	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Melilotus spp.	—	—	12	36	—	69	70	33	36	95	52	43	58	53	39	—	66	55	66	84
Oenothera sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	—
Panicum huachuacae	—	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Parthenocissus sp.	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Plantago lanceolata	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poa compressa	—	—	—	5	—	—	—	—	4	—	15	—	24	—	—	—	—	—	—	—
Poa pratensis	—	42	—	27	—	—	—	—	—	1	—	—	—	—	3	—	—	—	—	—
Polygonum spp.	—	—	1	—	2	—	—	1	—	—	—	—	—	1	—	—	—	—	1	—
Potentilla sp.	—	1	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Rhus radicans	6	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rubus sp. (blackberry)	—	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rubus sp. (dewberry)	—	8	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Rumex sp.	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sambucus sp.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Solanum carolinense	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Solidago spp.	—	—	—	35	—	—	—	—	—	—	—	1	13	1	2	—	—	—	—	3
Stellaria sp.	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tragopogon sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Trioda flava	—	2	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Ulmus americana	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Verbena urticifolia	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vitis yulpina	1	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total Plant Hits:	22	88	38	140	2	108	87	35	209	123	113	83	202	57	45	0	120	58	97	117

TABLE 2. Bareground, litter and plant hits recorded for 20 research sites in 1981. Numbers represent interceptions of each species during a total of 100 plumb line drops. Ten drops were made along each of ten lines centered in each site.

	W	A	B	C	D	E	F	G	H	I	J	K	L-O	M	N	P	Q	R	S	T
Bareground	—	—	5	—	100	41	29	14	33	—	1	7	1	1	4	29	1	14	1	3
Litter	100	100	95	100	—	59	71	86	67	100	99	93	99	99	96	71	99	86	99	97
Puffball	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Lichen sp. A	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Moss sp. A.	—	—	—	—	—	2	1	3	—	4	—	10	—	3	10	28	19	2	28	12
Maidenhair Fern	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Ebony Spleenwort	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acer negundo	—	—	—	3	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—	2
Acer saccharinum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Ambrosia sp.	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	3	—
Apocynum sp.	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—
Aster spp.	—	—	1	—	—	—	—	—	—	109	8	41	—	1	—	—	—	—	—	7
Brassica sp.	—	—	—	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—
Campsis radicans	—	—	—	—	—	—	—	—	102	—	—	—	—	—	—	—	—	—	—	—
Carya spp.	—	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cirsium altissimum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Cirsium vulgare	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Cercis canadensis	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cornus spp.	33	—	—	54	—	—	1	—	—	—	2	3	1	—	—	—	11	—	—	—
Crataegus spp.	—	1	—	—	—	3	—	1	—	—	1	3	—	1	—	—	6	—	—	10
Daucus carota	—	—	5	—	—	1	2	1	—	--	15	38	—	35	10	26	39	2	26	1
Diospyros sp.	—	—	3	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Elymis virginicus	—	—	—	—	—	—	—	—	—	—	—	—	8	—	—	4	—	—	—	—
Eupatorium altissimum	—	—	2	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—
Fraxinus sp.	—	2	—	—	2	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Geum canadense	—	—	1	—	—	2	—	—	1	1	5	5	—	8	10	—	5	1	—	1
Gleditsia triacanthos	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Graminae sp. A	—	—	48	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	8	4
Hierocium longipilum	—	—	1	—	—	—	—	—	—	—	—	2	—	—	4	—	7	—	3	—
Juglans nigra	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lactuca spp.	—	—	—	—	—	—	—	—	—	—	2	7	—	—	—	—	—	—	—	1
Lespedeza spp.	—	—	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lonicera sp.	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Malus sp.	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Melilotus spp.	—	—	2	—	—	110	63	50	93	71	13	13	1	3	45	6	126	3	53	1
Muhlenbergia sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Parthenocissus sp.	5	13	—	—	—	—	—	2	—	—	11	6	—	—	2	—	—	—	—	—
Poa compressa	—	9	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Poa pratensis	—	—	—	—	—	—	5	10	—	—	—	—	—	—	—	—	—	—	—	—
Pinus spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	11	—	—	—	26	—	—
Polygonum spp.	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	2	10	—	4	—
Potentilla sp.	—	— 2	—	—	—	—	—	—	—	—	—	—	2	2	—	3	1	—	—	2
Prunus serotina	1	—	—	12	—	—	—	—	8	13	—	4	2		—	—	—	1	—	—
Quercus spp.	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—	5	—	—
Rhus radicans	—	77	18	132	—	2	4	26	10	—	73	19	198	34	—	—	4	1	—	54
Rosa multiflora	—	—	—	—	—	—	43	4	3	—	—	—	1	—	—	—	—	—	—	
Rubus sp. (blackberry)	—	—	9	3	—	43	12	3	6	34	8	—	—	16	3	—	17	3	11	22
Rubus sp. (dewberry)	—	—	21	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Sanicula marilandica	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Sassafras albidum	1	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Solanum carolinense	—	—	—	—	—	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Solidago spp.	—	—	16	31	—	3	3	2	—	3	2	—	52	2	10	4	24	—	2	—
Spartina sp.	—	—	—	—	—	—	22	1	1	—	—	—	—	—	2	—	—	—	—	—
Ulmus americana	—	1	—	4	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—
Ulmus rubra	8	—	—	—	—	—	—	4	—	—	4	1	—	—	—	—	—	—	—	—
Urtica sp.	—	—	—	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—
Veronia altissima	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Viola spp.	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vitis vulpina	—	1	—	7	—	—	—	—	—	—	2	8	—	—	2	—	—	—	—	5
Total Plant Hits	52	125	157	248	2	179	161	114	226	239	149	175	267	117	103	75	269	46	138	122

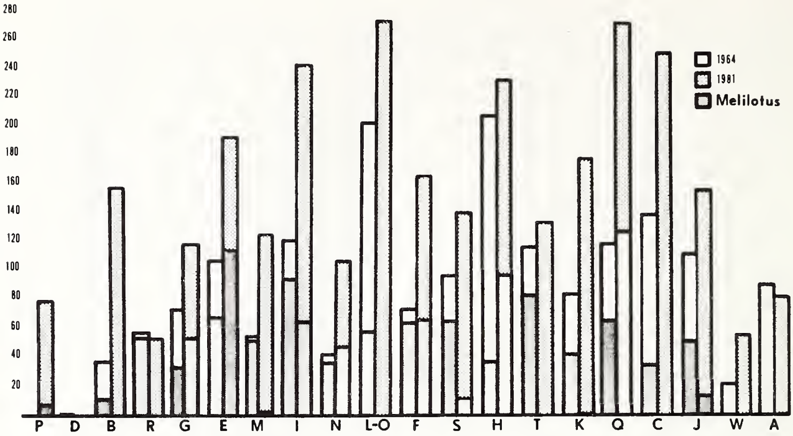


Figure 4. Total plant hits and *Melilotus* fraction sampled by modified point-contact system at 20 research sites in 1964 and 1981.

(*Cornus*), *Geum* and mosses are increasing in numbers and sites. Trumpet creeper (*Campsis radicans*) has failed to spread beyond its entrenchment site H. In 1964, only 8 sites scored over 100 plant hits, one site over 200. By 1981, sixteen sites exceeded 100 hits and five of these surpassed 200 in spite of early withering *Melilotus* (see discussion under plant methods).

The period from October 1, 1980 to March 31, 1981 was the driest six months in 100 years in Indiana, according to Meyer (8). Yucca plants near the stripmines were observed flowering three weeks earlier than usual. Such an early season and drought may have an impact on the plant sample. In 1964, Munsee noted in field notes that *Melilotus* was luxuriant and flowering in late June. In 1981, with the early spring, all but a few sheltered *Melilotus* finished flowering in mid-June and most were shriveled with withered leaves during the plant tallies. This could depress the apparent *Melilotus* count.

A decrease in herbaceous plants accompanies shading by trees. This results in the near-barren site D being clustered near forested sites W and A in 1964. In 1981, lack of plant hits excluded D from the clustering process. The larger number of plants and increase in species together produce a taller 'drawn out' dendrogram for 1981 (Figure 5).

When we build the dendrogram simply on whether each plant is present or absent at the site, D is clustered away from the forest with B and C (Figure 6, top). While plant hits overestimate bushy solitary plants and plant occurrence ignores plant abundance, plant frequency based on the percent of linear "plots" that intersect a plant at least once provide an intermediate picture (Figure 6, bottom). The fact that all of these approaches yield a site A clustered near site W indicates some congruence with biological reality since site A is unmined and reforesting. Occurrence and frequency dendrograms for 1981 (Figure 7) also have the long appearance from more plant species and generally higher numbers of hits. The lack of plants at site D in 1981 makes the orientation of the mined-site clusters, to the right, more subjective and many are left unordered due to a lack of criteria.

Most interesting are the 1964 and 1981 plant hit data clustered together (Figure 8). By 1981, only site H remained most like the 1964 association. 1981 site R, which visually appears most forest-like, is nearest the 1964 wooded site W. The vegetation of sites A and C, once similar to that of site W, are now more like the advanced stripmine sites.

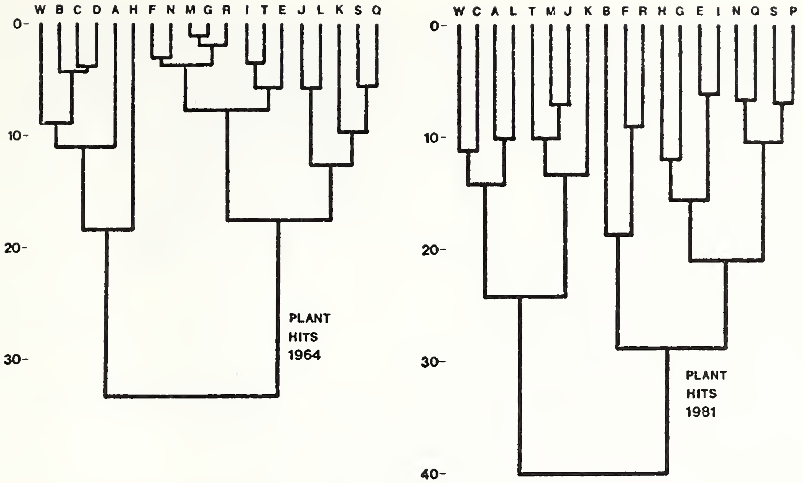


FIGURE 5. Dendrograms clustering sites on number of plant hits per species in 1964 and 1981. Successional stages would be read from right to left.

The mere presence and absence of plants, disregarding their numbers, shows much the same pattern (Figure 9). Site H again remains stagnant. The dichotomy between 1964 sites and 1981 sites is striking.

Discussion

Descriptions of revegetating stripmines are generally framed in terms of plant succession. Pre-settlement Indiana consisted of a mosiac of habitat types, defined by Daubenmire (4) as land areas capable of producing similar plant communities at climax. Fires, tornadoes, landslides, floods, insect infestations and other natural disasters permitted the growth of characteristic seral plant communities that eventually end at a climax com-

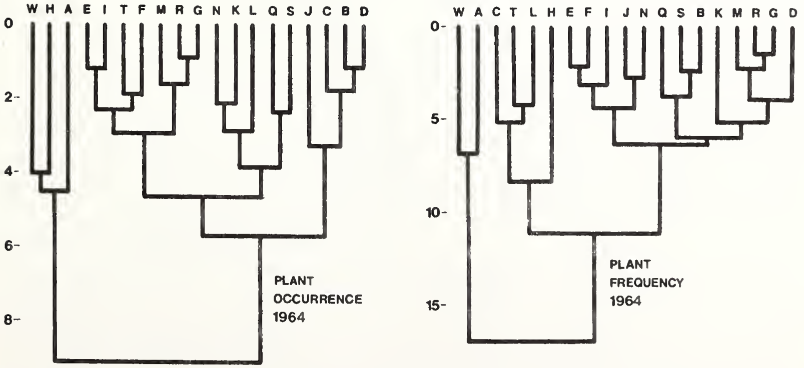


FIGURE 6. Dendrograms clustering 1964 sites on presence and absence of plants, and on plant frequency. Successional stages would be read from right to left.

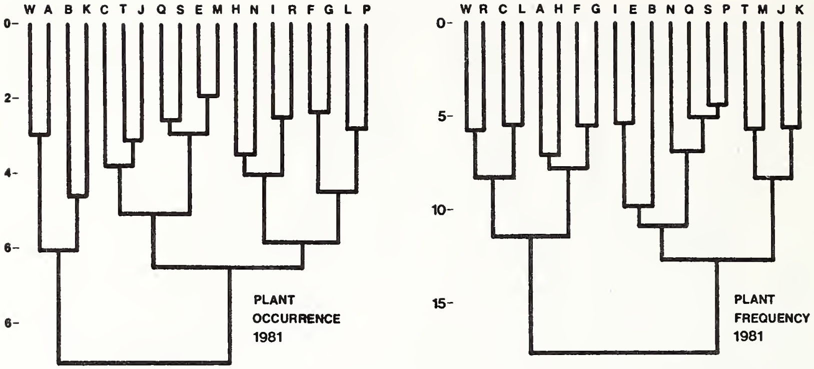


Figure 7. Dendrograms clustering 1981 sites on presence and absence of plants, and on plant frequency. Successional stages would be read from right to left.

munity. Additional disturbances by man make such seral communities more common. Where the soil layers are intact and a seed supply is available, succession occurs rapidly and is termed secondary succession. Where bedrock or regolith is exposed and no soil strata or seed supply are present, succession is termed primary, and thousands of years are required for the development of soil horizons. Stripmining that buries the topsoil and leaves a sterile subsoil-regolith mixture at the surface, is followed by an intermediate type of succession, undoubtedly much faster than primary but far slower than the return of a fallow farm field.

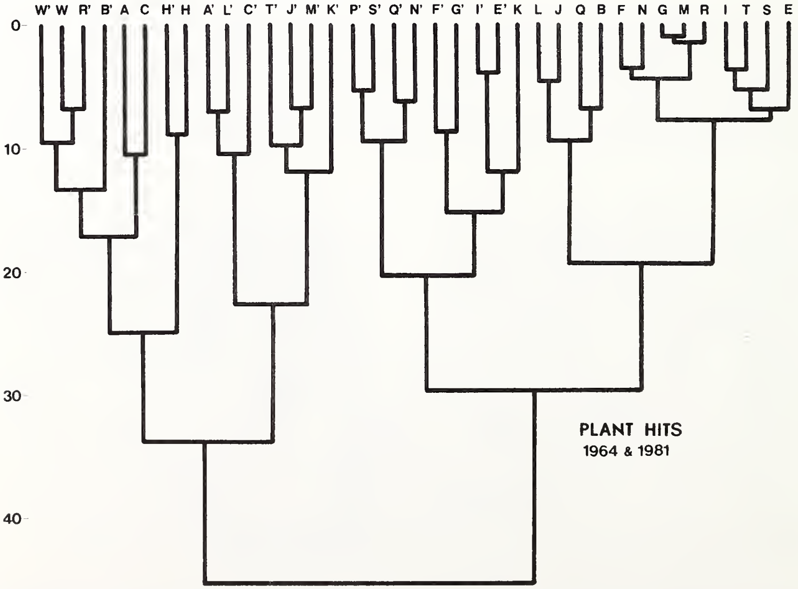


Figure 8. Dendrogram clustering all 1964 (W, A, B. . .T) and 1981 (W′, A′, B′ . . .T′) sites together on basis of plant hits.

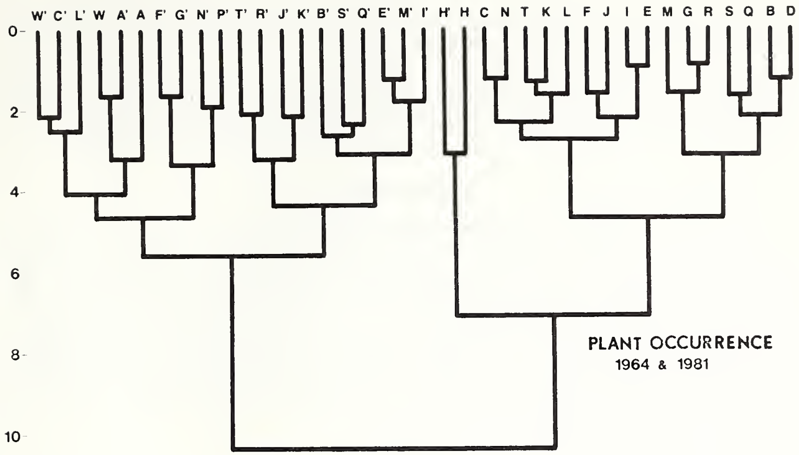


FIGURE 9. Dendrogram clustering all 1964 (W, A, B. . .T) and 1981 (W′, A′, B′. . .T′) sites together on basis of presence and absence of plants.

Spoilbanks are currently viewed as macrobiotically sterile, without significant seed banks, and totally inhospitable to most plant colonists for some time, as is shown here at site D. Some amount of time is therefore necessary for these spoils to pass a threshhold permitting some plant cover. The initial plants that invade these spoils await weathering of the spoils as is documented in this study. Significant site improvements provided by the plants themselves include the lowering of surface temperatures by shading the ground, the increasing organic matter as plant tissues accumulate, and the improved percolation of water through the soil due to root development.

The unreclaimed spoils are very rugged and present far more topographical and microclimatic variation than was originally present. These 1964 and 1981 studies are both embryonic stages in the exceedingly slowed development of these sites. At this time, environmental conditions are dissimilar enough that no one single climax community could be forecast. Redevelopment of plant communities and soil profiles roughly equivalent to pre-mining may never occur.

Summary

Bareground decreased and plant cover increased at all but one site as sampled by a point-contact method in 1981. Plant richness increased compared to 1964 and plant associations changed on many stripmine sites. Cluster analyses based on chi-square similarity were used to group similar sites on the basis of plant hits, plant frequencies, and plant occurrence. Arraying the clusters from still-barren sites to unmined sites suggests a tentative successional series. Sites array differently for herbaceous vegetation compared to arrays for physical factors, trees, or insects.

Plant succession is therefore used here in a descriptive sense, a counting and identifying of the organisms and a clustering of associations that occur serially on these spoilbanks. Once a threshhold, primarily measured here by pH, is exceeded, the sites vary widely in plant communities. It is possible that some will fail to converge eventually and, in the sense of Tansley (16), develop into a different edaphic climax on abnormal soil, a topographic climax due to aspect and microclimate, or topoedaphic climax due to both. The poison ivy of L-O, the pines of R, the willows of T, etc. should keep these sites distinct for many decades. A sobering conclusion unavoidable from the data is that site D failed to revegetate and shows no moderation of physical features permitting revegetation in the near future. This 40-year-old barren spoilbank and the variation in the revegetation of the other spoilbanks of essentially the same age must be considered in studies that try to deduce successional changes by examining multi-aged sites at one point in time.

Acknowledgments

The Clinton Chapter of the Isaac Walton League granted permission for the 1964 and 1981 studies. Munsee designed the original 1964 study and carried out the 1964 fieldwork. Schrock conducted the 1981 fieldwork, the between year comparisons, and wrote this text. We would like to thank our wives who were financially supportive throughout the research period. We are indebted to Dr. Leland Chandler, Purdue University, and Dr. Edward Martinko, University of Kansas, who served as major professors in the respective studies, and to Ralph Brooks of the Kansas State Biological Survey who identified some of the 1981 specimens.

Literature Cited

1. Byrnes, W.R. and J.H. Miller. 1973. Natural revegetation and cast overburden properties of surface-mined coal lands in southern Indiana. In Hutnik, R.J. and G. Davis (eds.) Ecology ad Reclamation of Devastated Land. Gordon and Breach, Inc.; New York.
2. Chambers, J.C. 1983. Measuring species diversity on revegetated surface mines: an evaluation of techniques. Intermountain Forest and Range Experiment Station, Ogden UT. Res. Paper INT-322.
3. Curtis, J.T. and R.P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology. 32:476-496.
4. Daubenmire, R. 1966. Vegetation: identification of typal communities. Science. 151: 291-298.
5. Deam, C.C. 1929. Grasses of Indiana. Dept. of Conservation. Publ. No. 82. State of Indiana, Indianapolis. 356 pages.
6. Fernald, M.L. 1950. Gray's manual of botany. 8th ed. revised. American Book Co., New York. 1632p.
7. Gleason, H.A. and A. Cronquist. 1963. Manual of vascular plants of northeastern United States and adjacent Canada. D. VanNostrand Co., New York.
8. Meyer, R.W. 1981. Insects and other arthropods of economic importance in Indiana during 1981. Proc. Ind. Acad. Sci. 91: 292-297.
9. Munsee, J.R. 1966. The ecology of ants of stripmine spoil banks. Ph.D. Dissertation. Purdue University, West Lafayette, Indiana. 243 pages.
10. Munsee, J.R. and J.R. Schrock. 1982. Comparison of ant faunae from unreclaimed coal stripmines in Indiana in 1964 and 1981. Proc. Ind. Acad. Sci. 92: 257-261.
11. Riley, C.V. 1973. Chemical alterations of stripmine spoil by furrow grading-revegetation success. In Hutnik, R.J. and G. Davis (eds.) Ecology and Reclamation of Devastated Land. Vol. 2. Gordon & Breach, Inc.; New York.
12. Schrock, J.R. 1983. The succession of insects on unreclaimed coal strip mine spoil banks in Indiana. Ph.D. Dissertation. University of Kansas, Lawrence, Kansas. 207 pages.
13. Schrock, J.R. 1985. Insect, Vegetation and Soil Recovery on Coal Spoilbanks—A 32-year study (Indiana). Restoration & Management Notes 3: 93-94.
14. Schrock, J.R. and J.R. Munsee. 1984. A comparison of soils on unreclaimed 1949 Indiana coal stripmine surfaces in 1964 and 1981. Proc. Ind. Acad. Sci. 94: 579-596.
15. Schrock, J.R. and J.R. Munsee. 1985. A comparision of trees and tree growth on

unreclaimed 1949 Indiana coal stripmine surfaces in 1964 and 1981. Proc. Ind. Acad. Sci. 95: in press.

16. Tansley, A.G. 1935. The use and abuse of vegetational concepts and terms. Ecology 16: 284-307.
17. VonDemfange, W.C. and D.L. Warner. 1975. Vertical distribution of sulfur forms in surface coal mine spoils. In Third Symposium on Surface Mining and Reclamation, Vol. I. National Coal Association, Louisville, Kentucky.

Effects of Fire on Invasion and Community Structure of a Southern Indiana Cedar Barrens

KIMBERLY A. WADE AND ERIC S. MENGES
Holcomb Research Institute
Butler University
Indianapolis, Indiana 46208

Introduction

Cedar barrens and glades are floristically related forest openings that occur on shallow soil over bedrock (often limestone) and support species adapted to extremes of light, temperature, and moisture (12). These areas are significant floristically and ecologically because they support species (some rare) of varying geographical distributions in unusual combinations.

In Indiana both glades and barrens occur on south-, southwest-, or west-facing slopes (1,4). When underlain by very shallow, azonal soils these areas are usually termed glades (9). They are generally incapable of supporting woody vegetation except in bedrock crevices where eastern redcedar (*Juniperus virginiana*) establishes (5). Although cedar is the most abundant woody species, prairie grasses and forbs dominate the openings. Areas with soil deep enough to allow substantial establishment of cedar are termed barrens (7) and often require fire to prevent tree invasion.

Fire suppression and cultivation have reduced Indiana barrens and glades to remnants (4), thereby causing some species to form small, disjunct populations. Continued fire suppression and subsequent forest encroachment could cause Indiana barrens and glades to disappear, resulting in extirpation of many species with restricted distributions. Little, however, is known about how forest closure is affecting glade species distribution and abundance, or how to manage and preserve the glade and barrens habitat.

Barrens and glades are distributed throughout the Central Basin of Tennessee (12, 34), the Big Barrens region of Kentucky (8), the east-central and southwestern Missouri Ozarks (11, 22), and northward across the Ohio River into the southern portions of Illinois (23, 26), Indiana (1, 4, 19, 21), and Ohio (40). Extensive presettlement grasslands, related to Indiana barrens, existed on limestone karst topography in the Big Barrens region of Kentucky (8). After settlement there, fire suppression caused a rapid shift to forest vegetation. Although little is known about Indiana barrens relative to their southern counterparts, it is thought that presettlement barrens in Indiana were also widespread, and that the same process of forest invasion occurred here (4). Deam (10), although aware of barrens in southern Indiana, appeared to underrepresent their flora when collecting species and constructing range maps.

Recently increased attention has focused on recognizing barrens and glades of biological significance, determining the flora they support, and preserving and managing the best remnants (1, 4, 19, 21). Quantitative studies are needed to characterize processes causing barrens closure and to determine how to best manage for glade-like habitat. Specifically, the optimal fire frequency for discouraging woody vegetation encroachment and encouraging the more restricted glade species needs to be determined. This paper describes a study on the effects of forest encroachment and fire on Leavenworth Barrens Nature Preserve, a limestone cedar barrens in Crawford County, with recommendations for intermittent controlled burns to maintain the site for barrens habitat.

Objectives

In response to the need for quantitative ecological work in Indiana cedar barrens and glade communities, Holcomb Research Institute (with partial support from the Division of Nature Preserves, Indiana Department of Natural Resources) initiated a monitoring study in 1985 at Leavenworth Barrens Nature Preserve (LBNP). The purpose of this study was to determine management practices that will (1) maintain openness of the barrens and (2) encourage persistence of glade species. Specific objectives included:

(1) determining the effects of a spring 1985 burn on LBNP plant communities, and formulating recommendations on use of fire for preserving the integrity of cedar barrens;
(2) describing the cedar barrens community by means of multivariate analyses and by relating environmental conditions, tree species structure, and herb-layer data to each other;
(3) relating the cedar barrens at LBNP to other high-quality cedar barrens and glades in the Midwest and southeast; and
(4) establishing a permanent grid system for future monitoring studies.

Study Site

Leavenworth Barrens Nature Preserve (LBNP), in Crawford County, Indiana, is a patchwork of four units (Figure 1). The 60-acre North Unit, located about one mile north of Leavenworth (T3S, R2E, S31) in the Harrison-Crawford State Forest, was the study site for this project. The site is floristically valuable, containing several rare species including the state-endangered glade endemic *Hypericum dolabriforme*, until recently thought to be extirpated from Indiana (1,3).

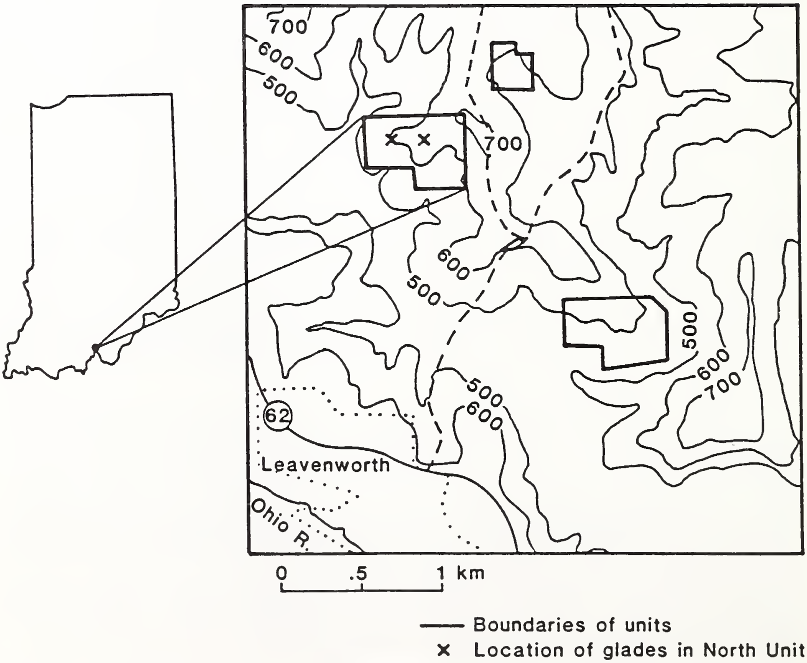


FIGURE 1. Location of Leavenworth Barrens Nature Preserve (LBNP) in Crawford County near the Ohio River in southern Indiana. This report details research in and around two glade-like openings (marked by x's) in the North Unit.

LBNP is one of a few Indiana barrens found in the Crawford Upland Physiographic Province (4); most presettlement barrens in the state are farther east in the Mitchell Plain (21). The LBNP substrate is Wellston silt loam (6-18 percent slopes), a well-drained soil formed from sandstone and siltstone and underlain by alternating layers of Mississippian shale, sandstone, and limestone (25,39). Wellston silt loams often support oak-hickory forest (24). At LBNP, outcroppings of limestone and shallow soil favor communities dominated by herbaceous plants. Soils of the Wellston series are usually about 130 cm deep (39); soil depth at LBNP was generally greater than 30 cm.

The North unit contains two openings (termed "glades" in this paper), located on and either side of an old logging road on a southwest-sloping ridge, that grade to closed glade, open woods, and closed woods (Figure 1). The east and west glades—currently a little over 1 ha and 2 ha, respectively—have decreased in size because of woody encroachment (4). To prevent further closure of the openings and encourage persistence of glade flora, the Indiana Department of Natural Resources burned portions of both openings in March 1985.

Methods

Surveying

We constructed a 25 m × 25 m grid system in the North Unit of LBNP in 1985 using a transit, stadia rod, and measuring tape. Permanent metal rebars and associated wooden stakes marked the 75 grid points (Figure 2). The grid is rectilinear on a plane

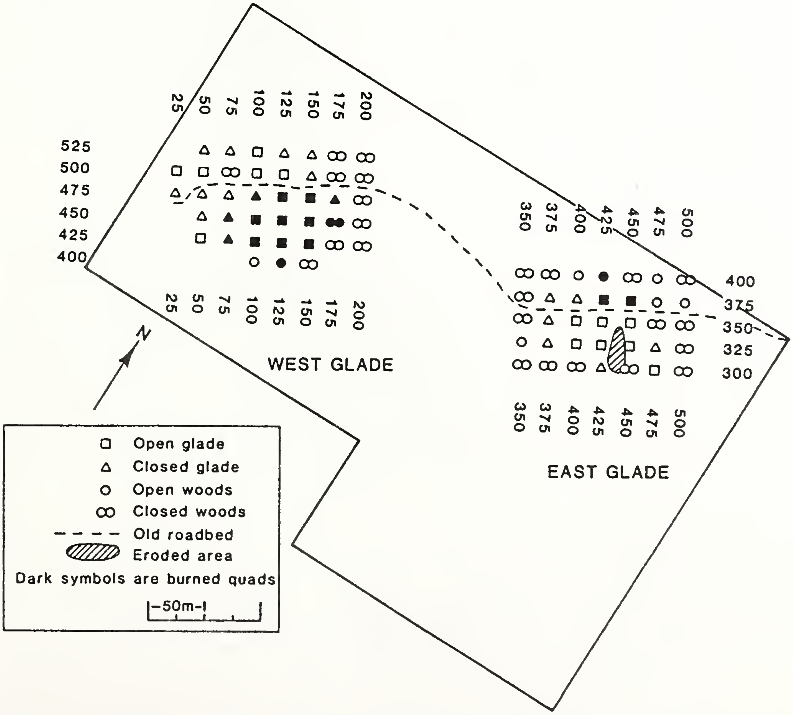


FIGURE 2. LBNP grid map showing eroded area, old logging road, and cover types at each grid point.

projection because the surveying incorporated corrections for slope. The grid, located relative to the Nature Preserve concrete marker at the northeast corner of the unit and the road leading into the openings, is rotated about 30 degrees from cardinal direction in order to follow the major ridge where the open glades are located.

Community Sampling

An initial species reconnaissance was undertaken on July 2-3, 1985. We sampled the plant community extensively on three trips to LBNP: July 8-10 (trees, shrubs, herbs, cover type), August 26-28 (herbs), and October 9-10 (late-flowering herbs). The species and diameter at breast height (dbh) were recorded for all woody stems $\geq$ 2.5 cm dbh occurring in a 100 m^2 circular plot (radius = 5.64 m) centered on each grid point. (This information is referred to as tree data). Percent cover, designated as cover class [0-1% (1), 1-7% (2), 7-25% (3), 25-50% (4), 50-75% (5), 75-93% (6), 93-100% (7)], was recorded for all herb and woody species with stems < 2.5 cm dbh in 10 m^2 circular plots (radius = 1.78 m) centered on the grid points (herb-layer data). Maximum cover achieved by each species was used in subsequent analyses.

Species difficult to identify were marked on the July trip for future identification. We collected plant vouchers for 110 species, largely grasses, legumes, and composites. Nomenclature for species identification follows Gleason and Cronquist (16), while Gleason (15), Gleason and Cronquist (16), and Graves (17) were used for keying. All vouchers were compared with specimens in the Friesner Herbarium at Butler University.

We also recorded cover type at each grid point and approximated borders of cover types between grid points. Cover types were unburned open glade and burned open glade ($\leq$ 25% canopy), unburned and burned closed glade (between 25% and 50% canopy), burned and unburned open woods (between 50% and 75% canopy), and closed woods (> 75% canopy). Closed glade and open woods intergraded but closed glades had more vertical layers (e.g., more shrubs) than did open woods, and cedar was more dense than in open glades.

Soil Sampling

Surface soil samples were collected from each grid point on August 26-28, 1985. The samples were analyzed for pH with a Fisher portable pH meter and a combination electrode in a solution of soil and 0.01 M $CaCl_2$ (36). For analysis of 11 elements (P, K, Ca, Mg, B, Mn, Fe, Cu, Zn, S, Al), samples from similar cover types were combined into 15 composite samples. These samples were sent to the Feed and Fertilizer Laboratory, Louisiana State University (Baton Rouge) where they were wet-ashed with perchloric and nitric acids for elemental analysis. Total, P, B, and S were determined with Technicon Autoanalyzers; samples were analyzed for K with a flame photometer; an atomic absorption spectrophotometer was used for determination of levels of total Ca, Mg, Mn, Fe, Cu, Zn, and Al.

Analytical Methods

Data were analyzed on the Butler University VAX-VMS system with @ORD (27) and SPSS-X (37) software. Multivariate analyses were applied to the community data (using @ORD) to classify and ordinate samples and species, as follows.

We used DECORANA (detrended correspondence analysis) to order quadrats by their dissimilarity in species composition (based on herb-layer cover class), and to order species by their dissimilarity in distribution over quadrats. DECORANA is an ordination technique that is generally successful in removing the arch distortion characteristic of some other ordination methods (13,18). Overlays of environmental data (cover type, soil data, tree basal area, tree density, and elevation) and correlations of environmental data with ordination axis scores facilitated interpretation of ordination results.

TWINSPAN (two-way indicator species analysis), a polythetic divisive technique (13,14), classified quadrats into various groups according to indicator species (species that best separate groups of quadrats). Further divisions on each subgroup produced smaller subgroups.

Discriminant analysis distinguished burned and unburned glades according to linear combinations of species abundance (38), thus maximizing distances between these two discrete cover types. Diversity was measured by species richness and evenness (33).

Results and Discussion

Flora of Leavenworth Barrens Nature Preserve

Two striking floristic features of LBNP are its diversity and its high proportion of native species. With 162 vascular species sampled (plus three fruticose lichens), LBNP has more species than are reported from most other glades and barrens. For example, Baskin and Baskin (7) reported 148 herbaceous vascular plants from five cedar glades in the Big Barrens region of Kentucky; however, the largest number in any single glade was 79 compared to the 107 herbaceous species at LBNP. Out of 313 plots in 10 cedar glades of central Tennessee, Pearsall et al. (32) found 140 taxa. Quarterman (34) found a comparable number of species (166) when she sampled 22 glades. (She also found 191 species in glade woods.) Although our rather large species list may reflect inclusion of several cover types and sampling of a large total area (750 m^2) at one site, high diversity may also be an inherent property of LBNP and one indication of its value as a natural area. Of the 107 herbs at LBNP, over 80% are native perennials. Only 4-6 species (depending on interpretation) have been introduced, or only about 3% of the flora, confirming LBNP as a high-quality site. Blue Licks, a cedar glade in Battlefield State Park, Kentucky, is comparable to LBNP, having six introduced taxa (9). Other representations of introduced taxa in Kentucky glades are somewhat higher, ranging from 13% to 25% (5,7,20).

The 162 vascular plant taxa represent 101 genera and 48 families. Compositae have the greatest number of representatives (34 species), followed by Gramineae (15 species), Leguminosae (15 species), and Rosaceae (10 species). Over two-thirds of the flora are herbaceous (107 taxa), representing 31 families. Most characteristic glade species were found largely in open and closed glade cover types.

LBNP vegetation has distinct affinities to cedar glades outside Indiana. Of 155 taxa that appeared in sampling quadrats at LBNP, 67 species (43.2%) were listed as constituents of two or more cedar glades in Missouri (11,22), Illinois (23,26), Tennessee (6,31,32), and Kentucky (5,7,9,20); and 36 species (23.2%) were listed in four or more of these studies. *Hypericum dolabriforme* represents the only cedar glade endemic found at LBNP (6) and is one of 10 species rare to Indiana that may be found at LBNP (Table 1).

Herb species quadrats supported between 6 and 38 species, averaging 20.4 species per 10 m^2 area. Species richness was greater in glades (11-38 species, mean 24.5) than in woods (6-26 species, mean 15.2); this difference was highly significant ($t = 7.16$, $p < 0.001$). However, evenness was similar among glades and woods. Among glades, closed glades had greater species richness (28.3 vs. 21.4, $t = 3.83$, $p < 0.001$) and greater evenness ($p < 0.001$) than open glades. In comparisons of burned vs. unburned open glades and open vs. closed woods, no differences were evident in either diversity measure.

TABLE 1. Rare species at LBNP.

Species	Status in Indiana*
Aster oblongifolius	Endangered
Galactia volubilis var. *mississippiensis*	Endangered
Hypericum dolabriforme	Endangered‡
Liatris squarrosa	Rare
Linum sulcatum	Endangered**
Pinus virginiana	Rare‡‡
Rudbeckia fulgida	Endangered**
Sisyrinchium angustifolium	Endangered**
Spiranthes tuberosa	Endangered
Zizia aptera	Endangered**

* After Bacone and Hedge (3), updated by Indiana Division of Nature Preserves.
** Not seen or sampled in 1986.
‡ Status changed from extirpated to endangered after rediscovery (1).
‡‡ Probably planted at LBNP.

Ordinations of the Herb-layer Vegetation

Herb-layer species at LBNP appeared to be distributed largely in response to the degree of openness of their habitat. A cover-type overlay on a DECORANA ordination shows that the first axis of variation (with eigenvalue = 0.416) clearly separated quadrats in closed woods from quadrats in open glades (Figure 3). Both closed glade and open

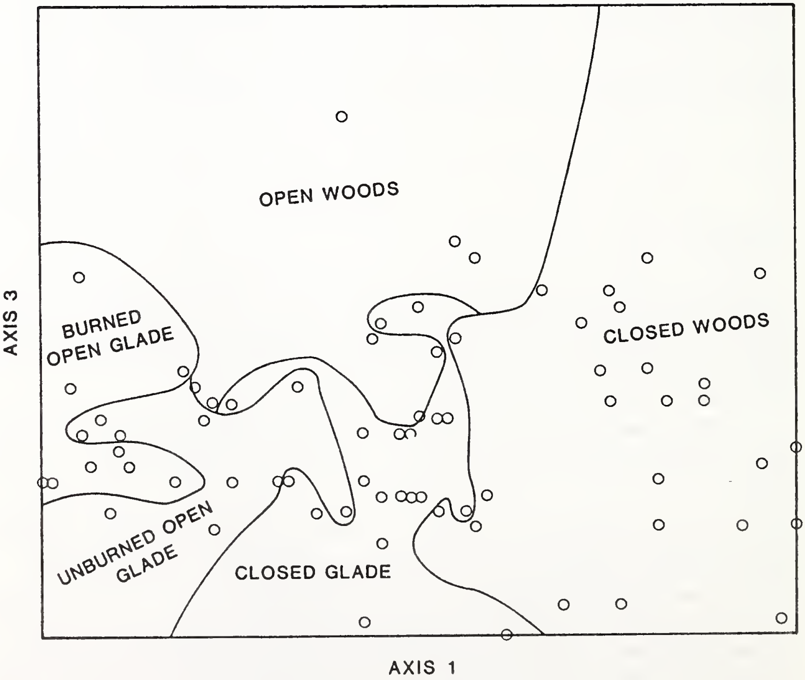


FIGURE 3. DECORANA ordination of herb species found in five or more quadrats at LBNP. Circles show location of quadrats in ordination space defined by axes 1 and 3. Lines separate different cover types.

woods cover types occupied intermediate locations on the first and second axes, but were clearly distinct on axis 3 (Figure 3).

Herb species composition was influenced primarily by the amount of woody cover and the relative dominance of *Juniperus virginiana*. Tree basal area varied strongly and monotonically along axis 1 of the herb ordination ($r = 0.74$, $p < 0.001$). *J. virginiana* relative dominance varied inversely ($r = 0.68$, $p < 0.001$) so that all areas with greater than 80% *J. virginiana* dominance were placed on the left 60% of this ordination.

Closed woods appeared to form an especially distinct group clearly differing from open woods and all types of glades. Species placement on DECORANA ordinations suggests that at LBNP a few woody species were characteristic of the herbaceous stratum in closed woods, as compared to glade species. Particularly associated with closed woods were the understory shrub *Symphoricarpos orbiculatus*, the understory herb *Polygonatum biflorum*, the vines *Rhus radicans*, *Dioscorea quaternata*, and *Parthenocissus quinquefolia*, and several tree species present in the herb layer of closed forests (*Celtis occidentalis*, *Cercis canadensis*, *Acer saccharum*, *Ostrya virginiana*, *Carya glabra*, and *Prunus serotina*). All species listed above were placed on the right 30% of the DECORANA first axis.

Herb species composition differed between glade areas burned in the spring of 1985 and unburned areas. Quadrats separated partially along the first axis of DECORANA ordinations, with some additional distinctions along subsequent axes (Figure 3). Burned quadrats were less similar to other areas of LBNP than were unburned areas, which occupied an intermediate position on axis 1, suggesting that burning has favored open conditions. Species on the extreme left of axis 1, suggesting an association with burning, included *Sorghastrum nutans*, *Solidago rigida*, *Liatris spicata*, *Polygala ambigua*, and *Desmodium rigidum*. *L. spicata* does not appear harmed by fire, which increases its success in burned areas (28,30).

In terms of herb species composition, quadrats typed as closed glade and open woods represented intermediates. Ordinations did not separate these two cover types until the third axis (eigenvalue = 0.168) (Figure 3), suggesting fairly subtle differences between them. Open woods were characterized by *Lespedeza intermedia*, *L. procumbens*, *Stylosanthes biflora*, and *Helianthus divaricatus*, while closed glades included *Geum virginianum*, *Scutellaria incana*, and *Oxalis stricta*.

Quadrat location was closely related to scores on the second DECORANA axis (eigenvalue = 0.201). Quadrats located in the eastern part of the gridded area tended to be located above the western quadrats on axis 2 (Figure 4). The separation was clearer in glades (open and closed) and open woods than in closed woods. Eastern quadrats were located farther uphill; elevation, therefore, showed a strong relationship with axis 2 ($r = 0.51$, $p < 0.001$).

These ordination patterns may also reflect environmental variables other than woody vegetation cover and burning (29). Other ordinations revealed that surface soil pH varied significantly with axis 2 ($r = 0.32$, $p < 0.001$) as did the concentrations of seven elements (P, Fe, Ca, K, Mg, B, and S). The heterogeneity of east and west glades may therefore be exerting some influence on soil chemistry. The third axis pattern of closed glade vs. open woods also reflects soil pH ($r = -0.50$, $p < 0.001$); from closed glade to open woods, pH changes from over 7 to less than 4.5. Lower soil pH can be expected in open woods areas where tannins from oak leaves tend to acidify the soil. The relationship of other environmental variables (aspect, slope angle, soil texture, and other drainage factors) to ordination patterns may be significant enough to merit further exploration.

Classifications of the Herb-layer Vegetation

Classification of herbaceous communities at LBNP confirms ordination results and provides additional insights into environmental influences and species groups. Two-way

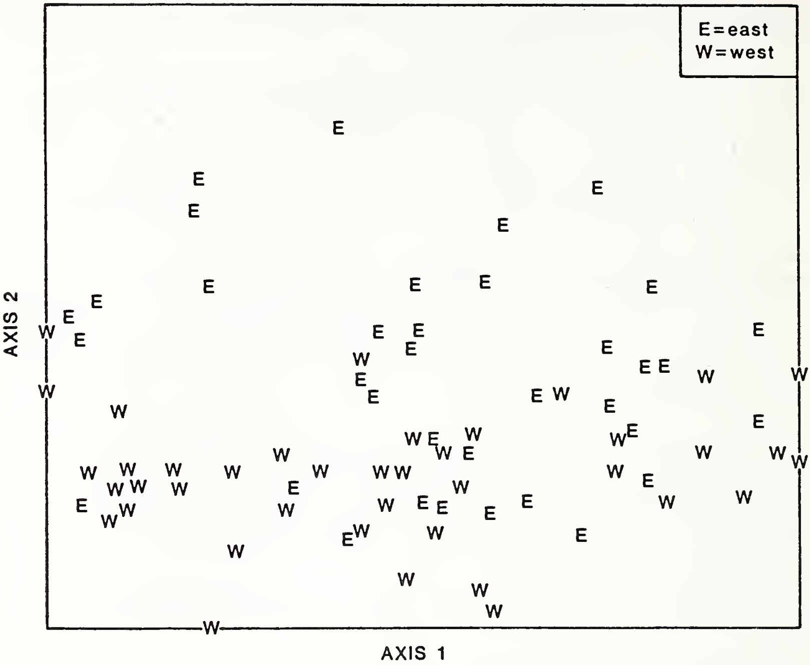


FIGURE 4. Overlay of quadrat location (east or west glade) onto first and second axes of DECORANA ordination of herb data.

indicator species analysis (TWINSPAN), which clusters groups of both samples and species, was used.

The initial TWINSPAN division separated nearly all woods quadrats (open and closed) from all open glade quadrats. Closed glade quadrats were placed on both sides of this initial division. Legumes were a conspicuous component of open glades at LBNP; two legumes indicated open glades (*Cassia fasciculata* and *Strophostyles umbellata*). The initial TWINSPAN division, when plotted on the DECORANA ordination, split the first axis in two (Figure 5).

The second level of division continued to separate quadrats based on the degree of openness of the vegetation. A set of open glade quadrats characterized by the prairie grass *Sorghastrum nutans* was distinguished from a group of open and closed glade quadrats, with a *Panicum* species and *Rosa carolina* as indicators (Figure 5). Species richness was considerably higher in the latter group (19 vs. 27 per quadrat). The division was also primarily between east and west glades (see Figure 4). *S. nutans* characterized the uphill, eastern glade. Again, the east vs. west differences may have been due to unmeasured environmental differences in moisture regime.

The other level-two division separated closed woods quadrats, characterized by three vines (*Parthenocissus quinquefolia*, *Rhus radicans*, and *Dioscorea quaternata*) and an understory herb (*Viola* sp.) from more open communities indicated by *Potentilla* sp. *Danthonia spicata*, and *Vaccinium stamineum*. The latter quadrat group included several intergrading cover types. This level-two division fell primarily across the first axis of the DECORANA ordination, which summarized species response to site openness.

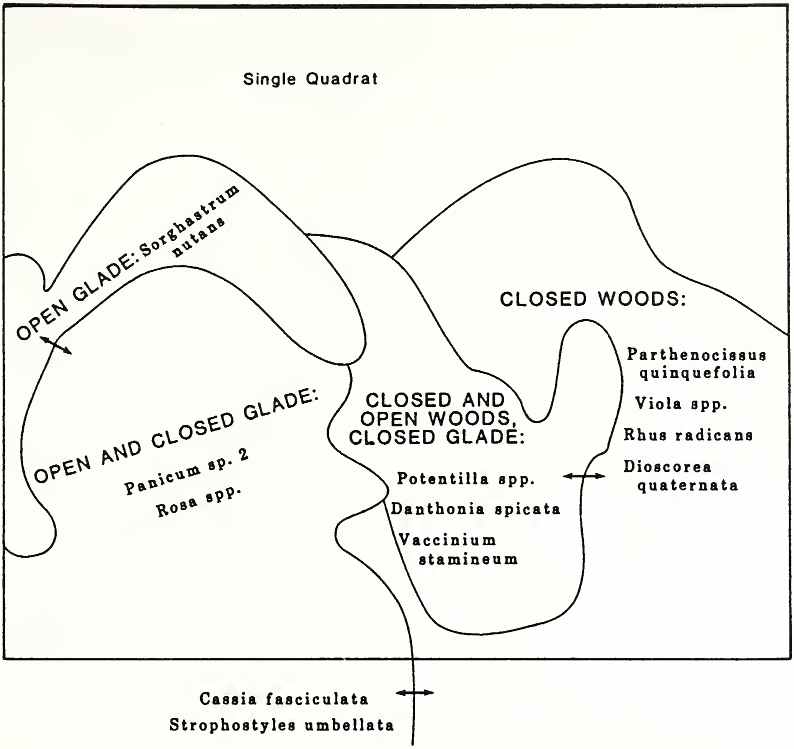


FIGURE 5. Plot of major TWINSPAN classification groups onto first two axes of DECORANA ordination of herb samples. The first division is shown at the bottom of the graph and second divisions within the ordination by arrows. Indicator species for each division are shown.

At the third level of TWINSPAN division (Figure 6), burning became an important criterion for separation of open glades. Open glade quadrats divided into burned open glade (group A, indicator: *Liatris spicata*) and unburned open glade (group B, indicators: *Cornus florida*, *Helianthus divaricatus*), both with 19 species per quadrat. A TWINSPAN analysis on glade quadrats only (not shown) demonstrated burning effects to be second only to the degree of openness. In this second analysis, *L. spicata* and *Panicum* sp. characterized burned areas while *Sassafras albidum*, *Smilax glauca*, and *Acer rubrum* characterized unburned areas.

Another level-three division separated the mixed open glade/closed glade group into open glade (group C: *Liatris spicata*, *Lespedeza virginica*, 24 species per quadrat) vs. more diverse closed glade (group D: *Rhamnus caroliniana*, *Cornus florida*, *Rhus copallina*, 29 species per quadrat) (Figure 6). *C. florida* was the key indicator of closed glade in analyses excluding woods quadrats also (not shown). The significance of woody species in the herb layer suggests that woody plant invasion, turning open glade into closed glade, has important effects on herb species composition in general.

Woody species were also important indicators of an herb species division within closed woods (Figure 6). *Acer saccharum* indicated a group of quadrats (G) with low species richness (15 per quadrat), while *Fagus grandifolia* and three other species

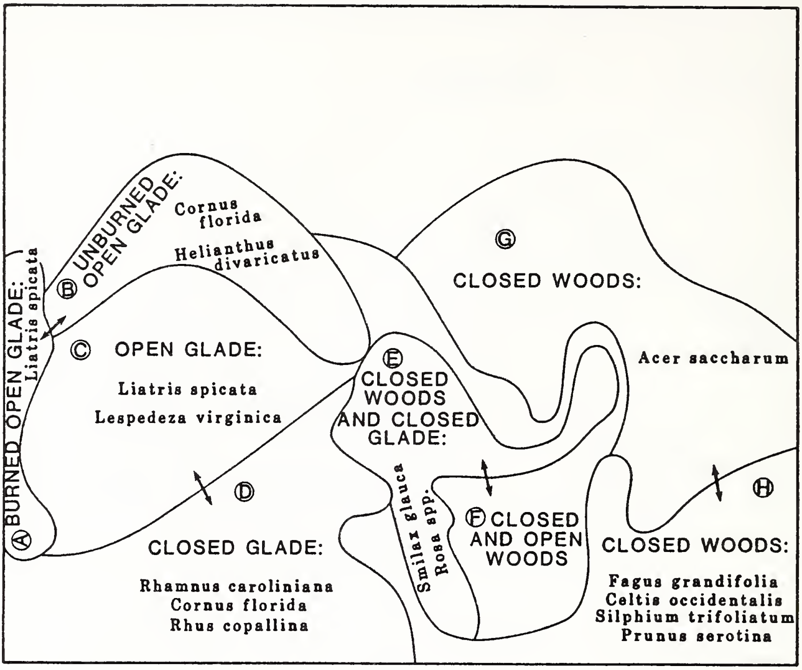


FIGURE 6. Plot of less major TWINSPAN classification groups onto first two axes of DECORANA ordination of herb samples. The third level of division is shown, with indicator species for each division.

characterized another group (H) with higher species richness (20 species per quadrat) than G. Finally, another third-level division separated closed glade (E) from open woods (F) quadrats.

Effects of Fire

We separated burned and unburned glade quadrats (all glades or just open glades), using discriminant analysis (not shown). Perfect classification was possible with knowledge of scores from 12-20 species, depending on the analysis. Fifteen herbs showed a preference for burning in a t-test ($p < 0.1$), seven of which were species with glade affinities. Several of the plants at LBNP (*Andropogon gerardi*, *Cassia fasciculata*, *Gaura biennis*, *Rudbeckia hirta*) also showed a positive response to fire in a southern Illinois barrens (2), where they either increased markedly in frequency after burning or had high frequency values (> 20%) in a burned area. LBNP glade elements exhibited slightly more of a preference for burning than did the prairie elements, but neither group showed a preference significantly greater than did herbs in general (Table 2). Although most herbs at LBNP (83.7% of the glade species and 85.0% of all woody species) showed no substantial preference for areas burned in 1985, the ten species typical of glades, barrens, and prairies that showed a preference were significantly more abundant in burned quadrats. Initial findings thus indicate a positive response to fire for some species typical of open habitats. Other glade and prairie plants may require more than a growing season to establish themselves in previously burned areas. Follow-up community sampling may reveal higher frequencies or greater abundance of glade and prairie species in burned open glades.

TABLE 2. Summary of herbaceous glade, herbaceous prairie, and woody species at LBNP, showing preference for burned and unburned environments.[1]

	No. Glade[2] Species	No. Nonglade Species	
Preference for Burned Areas	7	6	$x^2 = 2.02$ d.f. = 1 $p < 0.25$
Preference for Unburned Areas	0	2	
	No. Prairie[3] Species	No. Nonprairie Species	
Preference for Burned Areas	7	6	$x^2 = 0.010$ d.f. = 1 $p > 0.9$
Preference for Unburned Areas	1	1	
	No. Woody Species	No. Nonwoody Species	
Preference for Burned Areas	2	13	$x^2 = 9.97$ d.f. = 1 $p < 0.005$
Preference for Unburned Areas	7	2	

[1] Preference is significant using t-test, $p < 0.1$.

[2] Based on (5,6,7,9,11,20,22,23,26,31,32).

[3] Based on (8,35).

Intermittent fires may arrest invasion of woody species while at the same time allowing for establishment of glade species in the areas opened up. Additional studies should provide a suitable framework for determining the optimal fire frequency.

Some woody species (e.g., *Cornus florida*, *Juniperus virginiana*, and *Quercus alba*) were excluded by fire (Table 2). *J. virginiana* was particularly affected by the 1985 burn; we observed 14 dead tree-sized individuals in burned glade quadrats vs. three in unburned quadrats. Dead/alive ratios were highest for the smallest size classes of *J. virginiana*—i.e., those most vulnerable to fire. In a southern Illinois barrens (2), prescribed burning also decreased the abundance of *J. virginiana* and other tree species.

In time, lack of periodic burning may allow complete closure of the glades by mixed hardwood forest. In TWINSPAN analyses (Figure 6), *Cornus florida* is an indicator species for unburned open glades (vs. burned open glades)—and all indicator species for a group of closed glades are small, invading tree species. Classification of tree-sized individuals, based on relativized basal area (29), generated groups of closed glade quadrats with invading hardwoods (*C. florida* and *Sassafras albidum*) and woods quadrats characterized by canopy hardwoods (*Quercus spp.*, *Liriodendron tulipifera*, *Carya glabra*). Open glades in this classification contained only *J. virginiana* and *Pinus virginiana* as woody indicator species. Woods and closed glades also had greater tree species diversity than open glades (29). Other evidence for invasion into glades includes shifts to larger size classes for tree species found in both glades and woods.

Progressive invasion of open glades at LBNP parallels the successional processes that Quarterman (34) hypothesized for Tennessee cedar glades. Unlike the deeper-soil LBNP, Tennessee glades feature large rock outcrops that prevent complete canopy closure. LBNP is ecologically similar to the Big Barrens region of Kentucky (8) and southern

Illinois barrens (2), both of which contained large open areas only during a history of repeated burning. In the absence of controlled burning, these characteristics may make LBNP vulnerable to rapid and complete forest closure.

Summary

A floristic and community summary of Leavenworth Barrens Nature Preserve, a northern example of a limestone cedar barrens, shows high floristic diversity including rare species with high affinities to more southerly limestone glades. Comparisons with other cedar glades support the assessment of LBNP as a high-quality natural area.

Ordination and classification of one-year herb-layer abundance values reveal that composition of the herbaceous community is strongly related to the degree of shading by woody species. Plants most typical of glades, barrens, and prairies occur in the most open habitat. While forested portions of LBNP add to its overall diversity, woody encroachment into open glade-like areas excludes species most typical of cedar glades.

Initial findings indicate that controlled burning is a useful tool for maintaining barrens habitat. At least ten herbaceous glade and prairie species were significantly more abundant in burned quadrats than in unburned areas, while fire discouraged or excluded some woody species. Without controlled burns, progressive forest invasion may completely close the glade-like openings of LBNP. While fire is important to the integrity of the site, the optimal frequency and timing necessary to favor particular elements remain to be investigated.

Acknowledgments

We thank Stacia Yoon, Tom Armentano, Carol Cloonan, Jeannette Daniel, Julie Alexander, and Bruce McCune for field assistance. Bruce McCune and Tom Armentano helped with identification of lichens and vascular plants, respectively. George Yatskievych and Lewis Johnson at the Deam Herbarium verified some of our specimens. Soil analyses were carried out by the Louisiana State University Feed and Fertilizer Lab and by Brad Carter at Butler University. Stacia Yoon and Dave Shelton assisted with data handling; Ginger Williams typed this report, Colleen Baker drafted the figures, and Jim Rogers provided editorial assistance. Tom Armentano supplied useful comments on the manuscript. Special thanks to Jim Aldrich, for advice. This study was supported by the Division of Nature Preserves, Indiana Department of Natural Resources, and Holcomb Research Institute.

Literature Cited

1. Aldrich, J.R., J.A. Bacone, and M.D. Hutchison. 1982. Limestone glades of Harrison County, Indiana. Proc. Ind. Acad. Sci. 91:480-485.
2. Anderson, R.C., and J. Schwegman. 1971. The response of southern Illinois barren vegetation to prescribed burning. Trans. Ill. Acad. Sci. 64:287-291.
3. Bacone, J.A., and C.L. Hedge. 1980. A preliminary list of endangered and threatened vascular plants in Indiana. Proc. Ind. Acad. Sci. 89:359-371.
4. Bacone, J.A., L.A. Casebere, and M.D. Hutchison. 1983. Glades and barrens of Crawford and Perry Counties, Indiana. Proc. Ind. Acad. Sci. 92:367-373.
5. Baskin, C.C., and J.M. Baskin. 1975. The cedar glade flora of Bullitt County, Kentucky. Castanea 40:184-190.
6. Baskin, J.M., and C.C. Baskin. 1977. An undescribed cedar glade community in Middle Tennessee. Castanea 42:140-145.
7. ______. 1978. Plant ecology of cedar glades in the Big Barren region of Kentucky. Rhodora 80:545-557.
8. ______. 1981. The Big Barrens of Kentucky not a part of Transeau's Prairie Penin-

sula. In The Prairie Peninsula—In the "Shadow" of Transeau: Proceedings of the Sixth North American Prairie Conference (edited by R.L. Stuckey and K.J. Reese). Ohio Biol. Surv. Biol. Notes No. 15, Ohio State University, Columbus, Ohio, pp. 43-48.

9. ______. 1985. A floristic study of a cedar glade in Blue Licks Battlefield State Park, Kentucky. Castanea 50:19-25.
10. Deam, C.A. 1940. Flora of Indiana. Department of Conservation, Division of Forestry, Indianapolis, Ind. 1236 p.
11. Erickson, R.O., L.G. Brenner, and J. Wraight. 1942. Dolomitic glades of east-central Missouri. Ann. Mo. Bot. Gard. 29:89-101.
12. Freeman, C.P. 1933. Ecology of the cedar glade vegetation near Nashville, Tennessee. J. Tenn. Acad. Sci. 8:141-228.
13. Gauch, H.G. 1982. Multivariate Analysis in Community Ecology. Cambridge University Press, New York, N.Y. 298 p.
14. Gauch, H.G., and R.H. Whittaker. 1981. Hierarchical classification of community data. J. Ecol. 69:135-152.
15. Gleason, H.A. 1968. The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada. Vols. 1-3. Hafner Publishing Company, Inc., New York, N.Y.
16. Gleason, H.A., and A. Cronquist. 1963. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. D. van Nostrand Company, New York, N.Y. 810 p.
17. Graves, A.H. 1956. Illustrated Guide to Trees and Shrubs. Harper and Row, New York, N.Y. 271 p.
18. Hill, M.O., and H.G. Gauch. 1980. Detrended correspondence analysis, an improved ordination technique. Vegetatio 42:47-58.
19. Homoya, M.A. 1987. A floristic survey of a limestone glade in Versailles State Park, Ripley County, Indiana. Proc. Ind. Acad. Sci. 96: (in press).
20. Johnson, G.P. 1981. An unreported cedar glade in Warren County, Kentucky. Trans. Ky. Acad. Sci. 42:101-105.
21. Keith, J.H. 1980. Presettlement barrens of Harrison and Washington Counties, Indiana. Proc. Ind. Acad. Sci. 89:147.
22. Kucera, C.L., and S.C. Martin. 1957. Vegetation and soil relationships in the glade region of the southwestern Missouri Ozarks. Ecology 38:285-291.
23. Kurz, D.R. 1981. Flora of limestone glades in Illinois. In The Prairie Peninsula—In the "Shadow" of Transeau: Proceedings of the Sixth North American Prairie Conference (edited by R.L. Stuckey and K.J. Reese). Ohio Biol. Surv. Biol. Notes No. 15, Ohio State University, Columbus, Ohio, pp. 183-186.
24. Lindsey, A.A., W.B. Crankshaw, and S.A. Quadir. 1965. Soil relations and distribution map of the vegetation of presettlement Indiana. Bot. Gaz. 126:155-163.
25. Lindsey, A.A., D.V. Schmelz, and S.A. Nichols. 1969. Natural Areas in Indiana and Their Preservation. Indiana Natural Areas Survey, Department of Biological Sciences, Purdue University, Lafayette, Ind. 594 p.
26. Madany, M.H. 1981. A floristic survey of savannas in Illinois. In The Prairie Peninsula—In the "Shadow" of Transeau: Proceedings of the Sixth North American Prairie Conference (edited by R.L. Stuckey and K.J. Reese). Ohio Biol. Surv. Biol. Notes No. 15, Ohio State University, Columbus, Ohio, pp. 177-181.
27. McCune B. 1983. Multivariate Analysis on the @ORD System. University of Wisconsin, Departments of Botany and Zoology, Madison, Wis. Unpublished manuscript.
28. Medve, R.J. 1985. The effect of fire on the root hairs and mycorrhizae of *Liatris spicata.* Ohio J. Sci. 85:151-154.
29. Menges, E.S., and K.A. Wade. 1986. Community Analysis of Leavenworth Bar-

rens Nature Preserve (A Northern Example of a Cedar Barrens Ecosystem). Report to the Division of Nature Preserves, Indiana Department of Natural Resources. Report No. 76, Holcomb Research Institute, Butler University, Indianapolis, Ind. 65 p.

30. Menhusen, B.R. 1973. Ecology of the prairie species of the genus *Liatris*. In Third Midwest Prairie Conference Proceedings, Kansas State University, Manhattan, Kan., pp. 60-62.
31. Patrick, T. 1985. Flora of Crowder Cemetery Cedar Barren, Oak Ridge National Environmental Research Park, Roane County, Tennessee. Unpublished species list.
32. Pearsall, S., D. Eagar, E. Bridges, D. Durham, P. Hamel, L. Smith, and P. Somers. 1985. Developing a Community Based Natural Area Survey Technique in the Central Basin of Tennessee. Tennessee Department of Conservation, Nashville, Tennessee. Unpublished report.
33. Peet, R.K. 1974. The measurement of diversity. Ann. Rev. Ecol. Syst. 5:285-307.
34. Quarterman, E. 1950. Major plant communities of Tennessee cedar glades. Ecology 31:234-254.
35. Rock, H.W. 1974. Prairie Propogation Handbook (Sixth Edition). Wehr Nature Center, Whitnall Park, Wis. 74 p.
36. Schofield, R.K., and A.W. Taylor. 1955. The measurement of soil pH. Soil Sci. Soc. Am. Proc. 19:164-167.
37. SPSS Inc. 1986. SPSSX User's Guide. Second edition. McGraw-Hill Book Company, New York, N.Y. 988 p.
38. Williams, B.K. 1983. Some observations on the use of discriminant analysis in ecology. Ecology 64:1283-1291.
39. Wingard, R.C. 1975. Soil Survey of Crawford County, Indiana. USDA, Soil Conservation Service and Forest Service, and Purdue University Agricultural Experiment Station. 60 p + maps.
40. Wistendahl, W.A. 1975. Buffalo Beats, a relief prairie within a southeastern Ohio forest. Bull. Torrey Bot. Club 102:178-186.

ENGINEERING

Chair: David D. Chesak
Department of Physics
St. Joseph's College
Rensselaer, Indiana, 47987 (219) 866-7111

Chair-Elect:

ABSTRACTS

Fault Tolerant Computing. David D. Chesak, Saint Joseph's College, Rensselaer, Indiana 47978.——In the past 20 years, computing systems that have capabilities of self correction for certain types of hardware and software failures have reached a fair degree of sophistication. This paper surveys the presentations given at this year's International Symposium on Fault Tolerant Computing Systems.

Engineering Aspects of Heavy Duty, On and Off Highway, Trailers. Donald T. Chesak and David D. Chesak, Saint Joseph's College, Rensselaer, Indiana 47978.——This presentation covers design requirements of trailers for special hauling and configurations. State and federal regulations as well as customer specifications greatly influence the configuration of these vehicles. Some aspects of quality control will be covered.

PC-SIG: A Communications Systems Laboratory. Bruce Mueller, Bruce A. Black and David R. Voltmer, Rose-Hulman Institute of Technology, Terre Haute, Indiana 47803.——Traditional communications systems emphasize mathematical representation of signals and spectra. Many insights can be lost as students become preoccupied with the manipulation of mathematical functions rather than experimentation with actual signals and spectra. To enhance student learning, we at Rose-Hulman have implemented PC-SIG, an interactive software-based communications laboratory and graphics package. Students are able to learn by experimentation about time-frequency relations, filtering, and sampling. Since many students already own a PC or have access to one, PC-SIG enables them to investigate communications systems with expensive, dedicated equipment. The versatility of PC-SIG encourages students to test modulation schemes, noise analysis, and filter designs on their own. Future plans include integrating PC-SIG into a more complete package which collects real data via bus-controlled laboratory equipment.

SIG^{TM} is a product of Lawrence Livermore National Laboratory

The NASA Technology Utilization Program. John M. Ulrich, Indianapolis Center for Advanced Research, Indianapolis, Indiana 46704.——ARAC is one of seven NASA Industrial Applications Centers in the United States. It is located in Indianapolis, and is operated by the staff at the Indianapolis Center for Advanced Research (ICFAR). Its mandate to "broadly disseminate the technologies developed by NASA (and others) in the space program" came from then President John F. Kennedy in 1958.

This paper will present a few of the many accomplishments of the NASA/IAC program and, in particular, those of ARAC here in Indiana. Viewgraphs will be used to illustrate these accomplishments. The availability of NASA technology and how it is transferred, i.e., the methodology, will be discussed.

ENTOMOLOGY

Chair: Gene Kritsky
Department of Biology
College of Mount St. Joseph
Mount St. Joseph, Ohio 45030 (513) 244-4401

Chair-Elect: Vivie E. Dunn
Indiana State Board of Health
215 Monroe
Newburgh, Indiana 47630 (812) 853-2598

ABSTRACT

Insects in Traditional Chinese Medicine. Gene Kritsky, College of Mount St. Joseph, Mount St. Joseph, Ohio 45051.——China, during years of cultural isolation, developed a medical tradition that by western standards is unusual. In addition to the widely known acupuncture, some insects are highly regarded by the Chinese as being important ingredients in various medicinal concoctions. Cicadas, silkworms, blister beetles, cockroaches, and mantid ootheca are just a few examples of insects that can be obtained in traditional Chinese drugstores. Presented herein are several cases in which the use of insects in potions was prescribed to treat ailments such as typhus, ear infection, and migraine headaches.

Insects and Other Arthropods of Economic Importance in Indiana in 1986

Robert W. Meyer
Department of Entomology
Purdue University, West Lafayette, Indiana 47907

Introduction

The 1986 crop season followed a relatively mild winter; only December was cooler than average. Precipitation was average or above except in December and January. April was rather dry, enabling growers to complete ground preparation and seeding especially of corn early. Wheat development was rapid; the early harvest of wheat made second-crop planting feasible in many central counties. Usually only southern Indiana counties have that option. August and the first weeks of September were rather dry. The drought can't have been severe, however, since the estimated yield as of October 1 of corn was 127 bushels per acre, that of soybeans was 39 and that of wheat 43 bu/A. And in spite of the frequent and sometimes heavy rains that came in late September and October, the corn harvest was being completed at a faster-than-average rate. The abundance and severity of stalk rots made an early harvest highly desirable. The soybean harvest on the other hand lagged.

An estimated 6,000,000 acres were planted to corn (1985: 6,300,000 acres), 4,300,000 acres to soybeans (1985:4,500,000) and 900,000 to wheat (1985:770,000 acres) (1 October estimate).

Soil preparation in 1986 for corn was effected 36% by moldboard plow, 53% by conservation tillage and 11% no-till. For soybeans the percentages (in the same order) were 44, 46 and 10%.

Corn and Small Grains

The western corn rootworm (*Diabrotica virgifera virgifera*) is from year to year the most costly agricultural pest in Indiana because so many acres are treated routinely at planting time — normally 40% of all corn acreage. A survey conducted in July in 39 counties (usually 5 fields/county were visited and 10 widely separated plants were checked in each field) averaged 0.61 adults/plant, exactly the same as in 1985 and the 8 year average. Surveys of this type are only general indicators because timing is so important. There was a general consensus, however, among people who spend a lot of time in cornfields that this insect was at or below 1985 numbers. One researcher, Kurt Seevers, who made his second annual count of western corn rootworm adults on the shores of Lake Michigan noted a drop from nearly 900 per unit of measurement in 1985 to less than 200 in 1986. The reason for the large numbers on the shore is not well understood, however, and the data may reflect parameters other than population levels. In the July survey three districts averaged more than 1 beetle/plant: North Central with 1.15, C with 1.02 and SE (inadequately sampled) with 1.32. Only 1 county, Shelby, averaged more than 2. One Tippecanoe Co. field averaged 5.6 beetles/plant, the highest in the survey.

The first adult in a Tippecanoe Co. field regularly surveyed was collected on a yellow sticky trap in Tippecanoe Co. by 25 June, and trace numbers were encountered by 23 June from Sullivan Co. south to Spencer Co., and from there to Clark Co. in the SE district. Economic silk cutting was not observed.

The northern corn rootworm (*D. longicornis barberi*) was again at very low numbers, fewer than 0.08 adults/plant except in the NW district where they averaged 0.18/plant and in the C district, where they averaged 0.11/plant.

The European corn borer (*Ostrinia nubilalis*) under normal conditions is our second-most costly pest in Indiana corn. This year, by 17 June spring generation larvae in the

NC and NE districts were mostly in early instars with little midrib penetration. A week later in the SW and SC districts larvae were mostly late instars but no pupae were observed. Reports of economic numbers of either the spring or summer generation of larvae were few as well, so that what occurred in August came as somewhat of a surprise. Blacklight trap catches during the week from 23-29 August in Tippecanoe Co. were the largest ever recorded in a history of BL trapping dating back at least to 1964 — 7800 in one week. (The highest catch before this year's was 5390 collected in 1970 in Gibson Co.) Unfortunately this year only one BL trap was in operation, so data are limited. There were reports from other parts of the state of higher than usual numbers, and other states noted large flights of what were described variously as second generation or third generation flights. A third generation flight was postulated because that would have helped explain the larger than usual numbers. On the other hand the flight took place when the second generation flight normally takes place. Occasionally third generations do occur in southern Indiana and they are noted because there are early instars present during the fall corn insect survey in September and October; such larvae almost never reach maturity. The fall survey was to be dropped this year but because of the big flights a partial survey was conducted in which 3 (instead of 5) fields were visited in each of 3 (instead of 4) counties in each of the 12 corn borer districts. The state average in this survey was 143 large larvae/100 plants, exceeded only by the 1978 average of 200/100 plants.

The district with the highest average was in the northwest corner of the state which was represented by Newton, Jasper and LaPorte counties; 386 larvae/100 plants. This was expected since Jasper Co. (averaging 562 larvae/100 plants) is consistently a leader. The real surprise was the SE district which had the highest number in its history — 125 larvae/100 plants. The SE district — represented by Wayne, Rush and Decatur counties this year — has with parts of the SC district usually low numbers of larvae. The large August flight, incidentally, found little corn suitable for oviposition and was forced into such unusual crops as soybeans, snap beans, thick stemmed grasses, weeds and the like.

Black cutworm (*Agrotis ipsilon*) infestations were few, involving probably fewer than 1000 acres.

No attempt was made to estimate corn leaf aphid (*Rhopalosiphum maidis*) numbers, but there were few if any heavily infested fields in 1986.

Japanese beetles (*Popilia japonica*) were common in 1986 and were often seen on corn silks; no economic populations of adults were seen on corn, but larvae in damaging numbers were reported occasionally in corn fields where they fed on corn roots.

The 22nd annual survey of wheat conducted by the Agriculture Research Service of the USDA in cooperation with the Crop Improvement Association and the Entomology Department of Purdue University to detect Hessian fly (*Mayetiola destructor*) activity included 276 fields in 61 counties in Indiana. Hessian fly activity was less than usual. Mean percentage infestation for all cultivars was only 0.6, less than half last year's. During the past 5 years the rate has been as high as 5.5%. The mean number of puparia/100 stems was only 0.8, again the lowest in 5 years when all of the cultivars are included. The responses of wheat having some form of resistance (and which is commonly grown) follow. Cultivars having the H6 form of resistance were infested at the rate of 0.3% (209 fields surveyed), H5 was infested at the rate of 0.7% (20 fields surveyed), H3 = 2.8% (25 fields surveyed.) Only 15.2% of the fields visited were infested, half the average in the last 5 years. The only field having a percentage higher than 10% in 1986 was a Rush Co. field with a 30% infestation rate.

Forage Legumes and Soybeans

As much as 16% of the alfalfa stems showed evidence of feeding by 11 March in the SW district and a week later WC fields were showing feeding by the alfalfa weevil

(*Hypera postica*). By 24 March up to 44% of the alfalfa surveyed — averaging about 3cm — had tip feeding in the SW district. Up to 48 larvae/100 stems, up to 2nd instar, were present at that time. SC alfalfa still had low levels of tip feeding. A month later all WC fields had more than 50% with tip feeding and larval populations ranged from 1.4 to 3.5/stem. All the stems in a Vigo Co. field averaging 21cm showed tip feeding, averaged 3.5 larvae/stem. In that field and in the SW district, fields were silvering in spots — when damage is heavy the leaves become conspicuous in contrast with the green undergrowth. Alfalfa by this time was about 40cm tall and was beginning to bud. Probably half the fields in the WC and SW district should have been treated, although in some cases regrowth completely covered the damaged tips. There was little if any treating done in the SC district. A fungal pathogen, *Erynia* sp., which has been a factor during the last few years, was responsible for the weevil decline later.

Feeding was often evident on alfalfa in the northern districts and some scattered fields needed protection. There were also a number of fields in which the population of adults—the new adults—was so great that they seriously challenged the new growth and actually needed treatment.

More serious for the alfalfa growers in 1986 was the potato leafhopper (*Empoasca fabae*). One grower, seeing his stunted, yellowed alfalfa, blamed careless application of herbicide for the unusual color. Infestations this year tended to be severe, especially if the harvest was at all delayed. Probably all alfalfa in the state would have profited by treatment at least once.

The Mexican bean beetle (*Epilachna varivestis*) has for the third year in succession been absent from alfalfa fields. Adults prior to 1984 used alfalfa for food until soybeans were available but the hot, dry summer of 1983 virtually destroyed that pest. The species is however making a come-back, although isolated populations, not self-propagating, were observed in scattered locations on soybeans in the past 2 years. This year however there were isolated economic populations in Montgomery Co., according to reports, and conspicuous feeding was seen in fields next to State Road 47 southwest of Crawfordsville and in Parke Co. beside State Road 59 south of Guion even into Clay Co., often combined with feeding by the Japanese beetle. None of these infestions was economic.

Soybeans came through 1986 virtually unscathed by insects (except the infestations described above.) Soybean leafminer (*Odontota horni*) was seen in various NW counties but the infestations were light as also were the infestations by the green cloverworm (*Plathypena scabra*).

Fruit Insects

Apples and peaches came through the winter in excellent shape: 90% of the apple buds and 79% of the peach buds were alive on the first of April. A cold period during April reduced that number to about 50% of the buds and/or fruit. Delicious varieties and Jonathans suffered most, particularly in the WC and C districts.

Five pheromone traps each for redbanded leafroller (*Argyrotaenia velutinana*), obliquebanded leafroller (*Choristoneura rosaceana*) and codling moth (*Cydia pomonella*) were operated in Tippecanoe Co. during the season. The 5 redbanded leafroller traps collected 653 adults during this season. The average catch over 10 years is 1109 (Range 321-2359): in only one season was the catch lower than this season. Obliquebanded leafroller traps collected 189. The 10 years average in 355 (Range 99-715: in only one season were fewer collected. The 5 codling moth traps collected 230 adults males, the third highest catch in 10 years which averaged 194 moths/season, ranged from 38-458.

The apple maggot (*Rhagoletis pomonella*) was reported still flying on 6 October in Grant Co. Apparently the activity of this species was extended over a long period of time this year, and those who stopped treating for the pest at the usual time occasionally had maggot-infested fruit, according to reports.

Forests and Ornamentals

Virgil Knapp of the State Entomologist's office provided the following information on the gypsy moth (*Lymantria dispar*) in Indiana in 1986. Their extensive trapping program collected moths for the first time from the following counties: Clark, Crawford, Grant, Henry, Lawrence, Madison, Spencer, and Vanderburgh. These were all single moth catches. The largest catches were taken in Kosciusko Co., near the area mass trapped this year. Mass trapping has in the past been successful in containing potentially large populations, and now that the Kosciusko Co. population has been better defined it is hoped that massed trapping this area next year will effectively control it. There is also a population in Allen Co. that bears watching.

Virgil Knapp also provided a list of the top insect pests in connection with nursery inspections: 1. Japanese beetle. 2. Fall webworm (*Hyphantria cunea*) and oystershell scale (*Lepidosaphes ulmi*) (tie). 3. Pine scales (*Chionaspis heterophyllae*) and/or (*C. pinifoliae*). 4. Fletcher scale (*Lecanium fletcheri*). 5. Bronze birch borer (*Agrilus anxius*). 6. Zimmerman pine moth (*Dioryctria zimmermani*). 7. Honeysuckle aphid (*Hydaphis tartaricae*). 8. Honeylocust spider mite (*Eotetranychus multidigituli*). 9. Maple bladdergall mite (*Vasates quadripes*) and black vine weevil (*Otiorhynchus sulcatus*) (tie). 10. Bagworm (*Thyridopteryx ephemeraeformis*).

Insects of Man and Animals

For Medical Entomologist Dr. Michael Sinsko, who provided much of the following information, the big news among arthropods that attack man is the advent of a new mosquito species, *Aedes albopictus*. It was collected for the first time in Indiana by Vivie Dunn in Vanderburgh Co. It was later also collected in Indianapolis. The disjunct distribution is not unusual for this species since it gained access to this country in the water in imported used tire casings; hitch-hiking in this manner insures a disjunct distribution. Once present, it should have no difficulty in expanding its territories since it oviposits readily in all manner of man-made containers as well as such natural sites as tree holes. Dr. George Craig at Notre Dame is investigating its ability to survive our winters. A fierce nuisance, it is also a vector of several diseases.

Another unusual find this year: *Aedes aegypti* was collected in Columbus. It has usually been confined to the area south of the Ohio River, so its presence in Columbus would have attracted attention had it not been for *Aedes albopictus*.

Generally speaking, mosquitoes were less of a nuisance this year than in the past. Of the arthropod-borne diseases, by 10 November there had been 8 confirmed cases of LaCrosse encephalitis, none of either St. Louis or eastern equine encephalitis (although one horse died of the latter), a single possible case of Lyme disease and no reported cases of Rocky Mountain spotted fever.

Complaints of lice were fewer this year. This may be because there were fewer attacks but it may also be because victims are circumventing reporting agencies by home treatments using effective over-the-counter drugs. Flea complaints were also fewer than usual. Both John MacDonald, who works on them at Purdue, and Michael Sinsco agree that the baldfaced hornet was hard to find and that yellow jacket numbers were down as well.

For the past 6 years counts of horn flies (*Haematobia irritans*) and face flies (*Musca autumnalis*) have been made on a weekly basis on a herd of 10 mixed cattle on a farm in Warren Co. at about the same time of day. This year the counts of horn flies averaged 33.9 during the 13 weeks of the counts. The 5 year average is about 55/side. The highest count this year was the first made on 11 June, 129/side. Six weekly counts in Grant Co. averaged 33.9/side also.

Face fly averages in Warren Co. for 13 weeks were 14.5/face; the 5 year average was 11. Six counts in Grant Co. averaged 15.3, and a 16 count series in Tippecanoe Co. averaged 11.2. Counts were made this year by Carl Wallin and the details of this and previous years were made available by Cheryl Vail.

Beneficial Insects

Larvae of the alfalfa weevil were reared in sufficient numbers and frequency to get an estimate of the rate of parasitism in three districts. In the WC district 15 samples were reared: 12% of the larvae were parasitized by *Bathyplectes anurus*, 2% by *B. curculionis*. In the SW district 25% were parasitized by *B. anurus*, 21% by *B. curculionis* in 15 samples. In the SC district 29% were parasitized by *B. anurus*, 19% by *B. curculionis* in 12 samples. Samples collected from other districts and later samples from these districts were invaded by *Erynia* sp. that destroyed so many larvae that the samples could not be used, assuming that parasitized larvae were more likely to die of disease than healthy larvae. Excluding the 21-28 May collections, a total of 4570 larvae was reared.

Since sticky trap surveys in corn fields were discontinued during the year and the corn insect damage survey has been greatly reduced, this year there are no red coccinellid counts comparable to those of previous years. The sudden eruption of the sevenspotted lady beetle (*Coccinella septempunctata*) (It was collected in 1985 in nearly 50 counties for the first time) called for further information on its subsequent progress and, as important, its effect on other red coccinellids. So from early March until early September a kind of running record of all coccinellids observed in the various crops was kept. *Coleomegilla maculata* is still the most commonly observed lady beetle, having been observed 385 times. Next came the seven spotted lady beetle, seen 66 times. The convergent lady beetle (*Hippodamia convergens*) was seen 34 times, *Cycloneda sanguinea* 8 times, *Hippodamia parenthesis* 12 times and *Hippodamia tredecimpunctata* once.

By the end of the summer, incidentally, the seven spotted lady beetle had been collected in every Indiana county except 4: Carroll, Miami, Posey and Vanderburgh.

Host Range and Geographic Distribution of *Chionaspis heterophyllae* Cooley and *C. pinifoliae* (Fitch) (Homoptera: Diaspididae)

MARK H. SHOUR AND DONALD L. SCHUDER
Department of Entomology
Purdue University
West Lafayette, Indiana 47907

Introduction

Knowledge of the plants on which an insect pest is able to feed on better prepares plant protection personnel in anticipating the insect's occurrence on its hosts. Long-lived plants such as shrubs and trees are especially in need of monitoring closely since there are more opportunities for insects to develop into damaging populations on them. Various conifers used as ornamentals, Christmas trees and shelterbelts serve as hosts for two pernicious scale insects, *Chionaspis heterophyllae* and *C. pinifoliae* (Coulson and Witter, 1984; Miller, 1985). Maintaining an accurate host list for these two pests is essential to tree owners and arborists since they are able to quickly develop heavy infestations on their hosts (Stimmel, 1978).

Historically, the host list for *C. heterophyllae* has been abbreviated and limited to the genus *Pinus* (Merrill and Chaffin, 1923; Nakahara, 1982). This insect was originally described from *Pinus elliottii* (as *P. heterophylla*) by Cooley (1897). In contrast, *C. pinifoliae* has been reported feeding on several species of conifers, including members of the genera *Abies*, *Cedrus*, *Juniperus*, *Picea*, *Pinus*, *Pseudotsuga*, *Taxus*, *Torreya* and *Tsuga* (Dekle, 1976; McKenzie, 1956; Nakahara, 1982). Fitch (1856) originally described *C. pinifoliae* as feeding on "white pine".

Another valuable tool of plant protection personnel is knowing the geographical distribution of an insect pest. Both *C. heterophyllae* and *C. pinifoliae* are considered native to North America (Takagi and Kawai, 1967) but their natural distribution has been obscured due to movement of scale-infested hosts by nurserymen (Cumming, 1953; Furniss and Carolin, 1977; Peterson and DeBoo, 1969).

Fitch (1856) described specimens of *C. pinifoliae* from Illinois. (IL; hereafter all states will be abbreviated following the United States Postal Service method—see Nakahara, 1982). Ferris (1937) proposed a distribution "throughout Canada, the United States and at least northern Mexico". Nakahara (1982) concurred with Ferris (1937) and reported *C. pinifoliae* had also been collected in Cuba, El Salvador and Honduras in the New World and in England. Cooley (1897) described *C. heterophyllae* from FL and later reported it from RI (Cooley, 1899). Ferris (1942) proposed that this species was "characteristic of the southeastern United States and perhaps of the Caribbean region". Nakahara (1982) updated the distribution of this scale species as follows: AL, CT. DC, DE, FL, GA, LA, MA, MD, MO, MS, NC, NJ, NY, OH, PA, RI, SC, TN, TX, and VA in the United States as well as the Bahamas and Mexico.

There appears to be some interaction between the host range of *C. pinifoliae* and the geographic distribution and concentration of host trees, as reported by Peterson and DeBoo (1969). They observed that, in general, *Pinus* species were most frequently infested east of the Mississippi River in the United States whereas *Picea glauca* was a favored host in central Canada and *Pseudotsuga menziesii* was heavily infested in British Columbia. Edmunds (1973) stated that this host range and geographical distribution interaction illustrated "adaptation to specific conifer host species" by *C. pinifoliae*. He gave further evidence by reporting that this insect commonly developed outbreak populations in Spokane, WA, on *Pinus ponderosa* but did not utilize *Picea glauca*, *P. pungens* or

Pseudotsuga menziesii as regular hosts even though these potential hosts were present in the infested *Pnus ponderosa* stands.

The objective of this study was to record the observed host range and geographical distribution of *C. heterophyllae* and *C. pinifoliae* as in Indiana and from samples from other areas in the United States.

Methods

Host and geographical ranges for *C. heterphyllae* and *C. pinifoliae* were constructed from actual collections and from reliable literature accounts. Visits to several Christmas tree plantations throughout IN as well as examination of specimens received from nurserymen, foresters, entomologists and homeowners provided the basis for state distribution maps and host occurrences. National ranges were compiled from samples taken by the investigator or local collaborators and by careful literature searches.

All collections were verified to species based on adult female identifications (Kosztarab, 1963). Females were removed from host needles and either mounted in Hoyer's medium (Borror et al., 1981) or mounted permanently in euparol following the method of Wilkey (1977). A minimum of 5 slidemounted adult females for each collection site and host was used for these identifications.

Results and Discussion

Host Range. Host records for *Chionaspis heterophyllae* and *C. pinifoliae* observed for IN during this study are given in Table 1. *C. pinifoliae* was collected from several different conifers but *C. heterophyllae* had a narrower host range. There were 4 hosts common to both scales: *Pinus mugo*; *P. sylvestris*; *Picea abies*; and *Tsuga canadensis*.

TABLE 1. Host range observed in Indiana for *Chionaspis heterophyllae* (CH) and *C. pinifoliae* (CP) (1982-1986).

Conifer Species	CH Host*	CP Host
Picea abies	[X]	X
P. pungens		X
Pinus cembra		X
P. mugo	X	X
P. nigra		X
P. resinosa		X
P. strobus		X
P. sylvestris	X	X
P. virginiana	X	
Pseudotsuga menziesii		X
Tsuga canadensis	[X]	

* bracketed values from host-transfer studies — see Shour (1986)

Previous host records within IN are few and abbreviated. Dietz (1912) mentioned *C. pinifoliae* fed on "various conifers" with *P. strobus* being the most common host encountered. Additional state collections have been made on *Picea pungens*, *Pinus mugo*, *P. nigra*, *P. resinosa*, *P. strobus* and *P. sylvestris* (Amos, 1933; Schuder, 1983). Our results supported all previous works done in this state, as well as provided a list of other hosts for *C. pinifoliae*. In addition, a host list for *C. heterophyllae* within IN has been initiated.

Both *C. heterophyllae* and *C. pinifoliae* were observed feeding only on the foliage of their coniferous hosts. Previous reports by Cooley (1897, 1899) that *C. heterophyllae* fed also on the bark of new growth was not observed in this study nor has it been confirmed by other workers (ex. Dekle, 1976; Kosztarab, 1963).

National host records for *C. heterophyllae* and *C. pinifoliae* are given in Table 2. This is a compilation of the results of this study as well as data from selected literature accounts. This host list was not intended to be complete but serves to initiate a summary of specific hosts for both scale species in the United States. From this analysis, it was seen that there were 14 mutual hosts for *C. heterophyllae* and *C. pinifoliae*, the majority being *Pinus* species. It is expected that the host list for both scale species will increase as workers verify host and scale species present in their areas.

TABLE 2. National host range for *Chionaspis heterophyllae* (CH) and *C. pinifoliae* (CP) based upon several sources.**

Conifer Species	Documentation As	
	CH Host	CP Host
Abies alba		3
A. balsamea		4, 9
Cedrus deodara		8
Cedrus species		4
Juniperus species		4
Picea abies	9, 10	6, 9, 10
P. mariana		3
P. orientalis		6
P. pungens		4, 6, 9
Pinus banksiana		9
P. canariensis		9
P. cembra		10
P. clausa	9	4
P. contorta		5, 7
P. densiflora	9	
P. echinata (syn. *mitis*)	4, 9	
P. elliotti (syn. *caribaea, heterophylla*)	4, 9	4
P. glabra	9, 10	4
P. halepensis	4	
P. jeffreyi		7, 10
Pinus monophylla		2
P. mugo	9, 10	9, 10
P. nigra	4, 9, 10	6, 9, 10
P. palustris	4, 9	4
P. ponderosa		5, 10
P. resinosa	6, 9, 10	10
P. rigida	1, 6, 9	
P. strobus	9	6, 9, 10
P. sylvestris	4, 6, 9, 10	4, 6, 9, 10
P. taeda	4, 9, 10	4
P. thunbergii	4, 9, 10	4, 9
P. virginiana	9, 10	4, 9
Pseudotsuga menziesii (syn. *taxifolia*)		8, 10
Taxus brevifolia		8
Torreya californica		8
Tsuga canadensis	10	4, 6, 9, 10
T. caroliniana		9

** References: 1 = Andresen (1957); 2 = Brown (1965); 3 = Cooley (1899); 4 = Dekle (1976); 5 = Edmunds (1973); 6 = Kosztarab (1963); 7 = Luck and Dahlsten (1974); 8 = McKenzie (1956); 9 = Rhoades (1986); 10 = Current Study.

The presence of *C. heterophyllae* feeding on *Picea abies* and *Tsuga canadensis* was very notable. These observations indicated that *C. heterophyllae* was capable of feeding on conifers other than *Pinus*. The record of *C. heterophyllae* on *Picea abies* has been observed in the past in Georgia but only recently has a literature record been made (Rhoades, 1986). *Tsuga canadensis* may be a viable host for *C. heterophyllae* but this remains to be shown; this record and one of the *P. abies* references were the results of an artificial introduction to these conifers during separate experimentation (Shour, 1986). Previously, the host range distinction between *C. heterophyllae* and *C. pinifoliae* has been a major method of isolating these two scales as species in the field and, to some degree, systematically. Adaptation of *C. heterophyllae* to non-*Pinus* coniferous hosts tends to negate these major differences and will necessitate more careful species verification on non-*Pinus* hosts.

Geographic Distribution. The distribution of *C. heterophyllae* was widespread throughout the state of IN (Figure 1) and included the areas active in growing Christmas trees. This species was also collected from residential, commercial and institutional ornamental plantings. The occurrence of *C. pinifoliae* ws scattered throughout the state (Figure 1) and was primarily associated with various ornamental and natural plantings, although the species was present in some Christmas tree plantations.

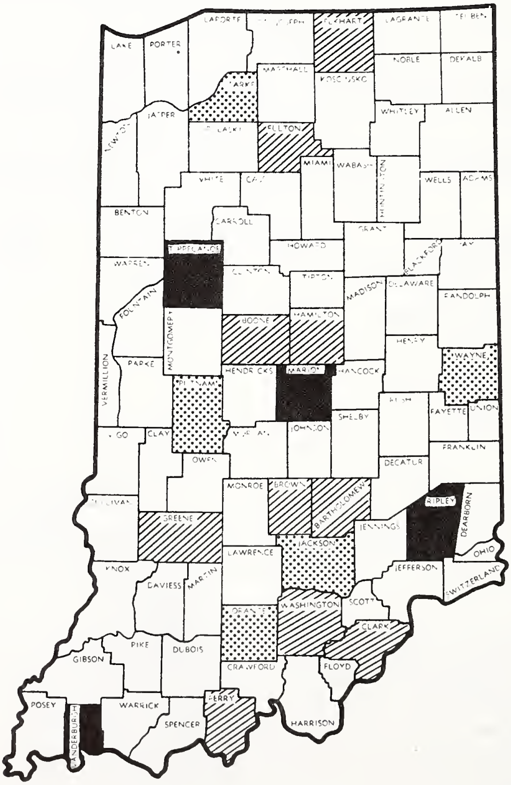


FIGURE 1. Distribution of *Chionaspis heterophyllae* (hatched lines) and *C. pinifoliae* (dots) in Indiana, based on collections from 1982-1986. Counties represented in black are where both scale species were collected. Unmarked counties were not sampled.

This state distribution for *C. heterophyllae* is considered the first verified report, whereas *C. pinifoliae* has already been observed in the state. About 1971, *C. heterophyllae* was first observed in IN at 3 sites (Rochester, Zionsville, and Columbus), but no formal record was made. Dietz and Morrison (1916) collected *C. pinifoliae* from central and southern Indiana and they proposed a statewide distribution for this species. We agree with Dietz and Morrison (1916) that *C. pinifoliae* is probably distributed throughout the entire state wherever suitable hosts exist. It is proposed that *C. heterophyllae* is more widespread in the state than Figure 1 indicates. A complete survey of IN is needed to better document the presence of both species and their hosts.

National collection records for *C. heterophyllae* and *C. pinifoliae* obtained in this study are presented in Figure 2. The presence of *C. heterophyllae* in IL, IN, KY and MI constituted new state records based on the distribution of Nakahara (1982). Although MacGillivray (1921) included *C. heterophyllae* in his treatise on coccids, there was no indication if this species was collected in IL or if it was included for completeness. Collections of *C. heterophyllae* from the other states in Figure 2 confirmed and verified the report of Nakahara (1982) for these specific states. Since *C. pinifoliae* has been known from all of the conterminous United States (Nakahara, 1982), these results served to verify some of these accounts and to show the scale's occurrence on both coasts. All records for both scale species were from biparental populations; an additional record was made of a parthenogenetic population in CA.

The United States distribution for *C. heterophyllae* is shown in Figure 3. This map

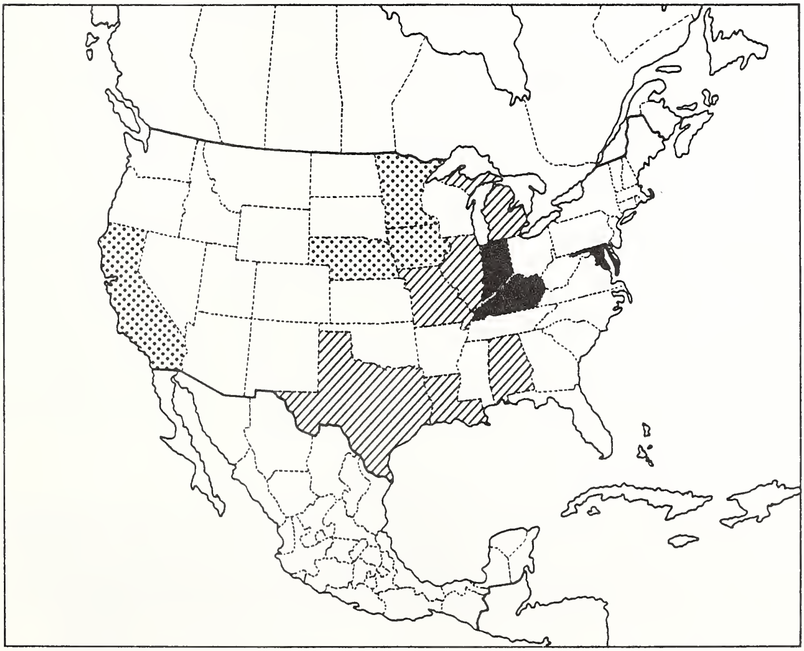


FIGURE 2. National collection records of *Chionaspis heterophyllae* (hatch lines) and *C. pinifoliae* (dots) during this study—1982-1986. The three states represented in black are where both scale species were collected. Collections and records were not available from unshaded states.

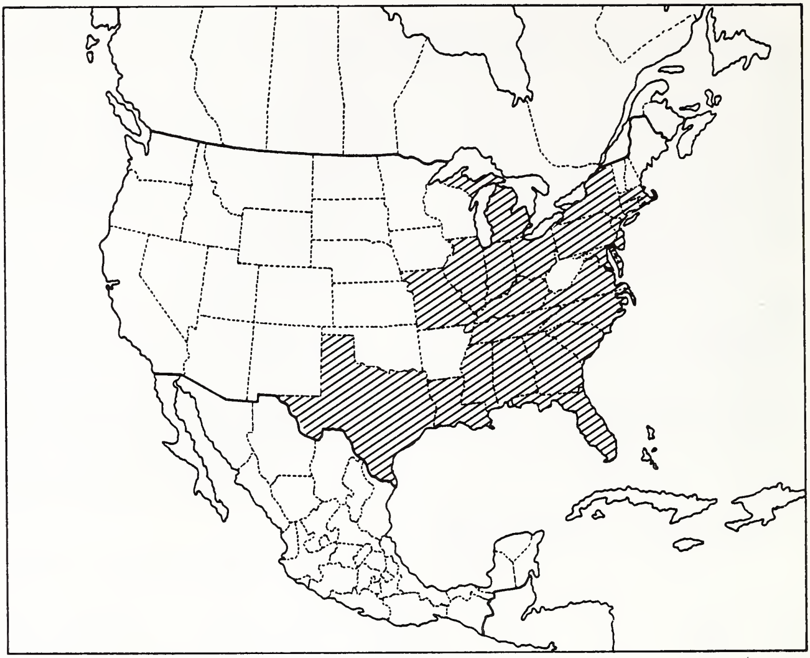


FIGURE 3. National distribution of *Chinoaspis heterophyllae*. Based upon actual collections during this study and records from coccidologists. Collections and records were not available from unshaded states.

was based on results from the current study as well as from reliable literature accounts (Andresen, 1957; Dekle, 1976; Kosztarab, 1963; Nakahara, 1982; Stimmel, 1978). The original Gulf States and Caribbean distribution proposed by Ferris (1937) has been expanded. This can be explained by: A) the movement of scale-infested stock via the nursery industry, Christmas tree growers (primarily with seedlings) and individual citizens transporting personal plants (Cumming, 1953; Furniss and Carolin, 1977; Peterson and DeBoo, 1969); B) the distribution of *C. heterophyllae* was broader than Ferris (1937) had imagined; and C) a growing awareness by entomologists of the presence of 2 scale species feeding on conifers.

Acknoledgments

The authors would like to thank Indiana's nurserymen and Christmas tree growers for their cooperation in this study. Appreciation also is extended to Philip T. Marshall (IN), Mark E. Ascerno (MN), Kent Widdicombe (NE), Raymond J. Gill (CA), Douglass R. Miller (MD), Daniel A. Herms (MI), Don Orton (IL), Abe Oliver (LA) and Barry L. Freeman (AL) for providing scale samples from their areas of the country.

Literature Cited

1. Amos, J.M. 1933. A list of Coccidae of Tippecanoe County and their hosts (Homoptera). Proc. Indiana Aca. Sci. 42: 205-208.

2. Andresen, J.W. 1957. *Phenacaspis heterophyllae* in New Jersey. J.N.Y. Entomol. Soc. 65: 81-84.
3. Borror, D.J., D.M. DeLong, and C.A. Triplehorn. 1981. Collecting, preserving and studying insects, p. 727. In An Introduction to the Study of Insects, 5th ed. Saunders College Publ., Chicago.
4. Brown, S.W. 1965. Chromosomal survey of the armored and palm scale insects (Coccoidea: Diaspididae and Phoenicoccidae) Hilgardia 36:189-295.
5. Cooley, R.A. 1897. New species of *Chionaspis*. Can. Entomol. 29: 278-282.
6. Cooley, R.A. 1899. The coccid genera *Chionaspis and Hemichionaspis.* Mass. Agric. Exp. Stn. Special Bull. No. 57.
7. Coulson, R.N. and J.A. Witter. 1984. Sapsucking insects and mites: Armored scales, Diaspididae, pp. 423-427. In Forest Entomology: Ecology and Management. John Wiley and Sons, New York.
8. Cumming, M.E.P. 1953. Notes on the life history and seasonal development of the pine needle scale, *Phenacaspis pinifoliae* (Fitch) (Diaspididae: Homoptera). Can. Entomol. 85: 347-352.
9. Dekle, G.W. 1976. *Chionaspis heterophyllae* Cooley: *Chionaspis pinifoliae* (Fitch), pp. 51, 55 and 175. In Arthropods of Florida and Neighboring Land Areas, Florida Dept. Agric. Conserv. Serv. Contrib. No. 60, Vol. 3.
10. Dietz, H.F. 1912. Scale insects of Indiana. Fourth Ann. Rep. State Entomol., pp. 145-226.
11. Dietz, H.F. and H. Morrison. 1916. The Coccidae or scale insects of Indiana. Eighth Ann. Rep. State Entomol., pp. 194-321.
12. Edmunds, Jr., G.F. 1973. Ecology of black pineleaf scale (Homoptera: Diaspididae). Environ. Entomol. 2: 765-777.
13. Ferris, G.F. 1937. Atlas of the Scale Insects of North America. Series I, No. 93. Stanford Univ. Press, Stanford, CA.
14. Ferris, G.F. 1942. Atlas of the Scale Insects of North America. Series IV, No. 406. Stanford Univ. Press, Stanford, CA.
15. Fitch, A. 1856. The pine leaf scale insect, *Aspidiotus pinifoliae*, new species. N.Y. State Agric. Soc. Trans. 15: 488-494.
16. Furniss, R.L. and V.M. Carolin. 1977. The pine needle scale, *Chionaspis [Phenacaspis] pinifoliae*, pp. 115-116. In Western Forest Insects. U.S. Dept. Agric. For. Serv. Misc. Publ. No. 1339.
17. Kosztarab, M. 1963. *Phenacaspis heterophyllae* (Cooley) and *Phenacaspis pinifoliae* (Fitch), pp. 91-92, 95-96. In The Armored Scale Insects of Ohio (Homoptera: Coccoidea: Diaspididae). Bull. OH Biol. Survey (n.s.), Vol. 2, No. 2.
18. Luck, R.F. and D.L. Dahlsten. 1974. Bionomics of the pine needle scale, *Chionaspis pinifoliae*, and its natural enemies at South Lake Tahoe, California. Ann. Entomol. Soc. Am. 67: 309-316.
19. MacGillivray, A.D. 1921. The Coccidae. Scarab Co., Urbana, IL. pp. 326, 347.
20. McKenzie, H.L. 1956. *Phenacaspis pinifoliae* (Fitch), pine needle scale, p. 149. In Armored Scale Insects of California. Bull. Calif. Insect Survey, Vol. 5.
21. Merrill, G.B. and J. Chaffin. 1923. *Chionaspis pinifoliae* (Fitch), *Chionaspis pinifoliae heterophyllae* (Cooley). Quarterly Bull. State Plant Board Florida 7: 215-216.
22. Miller, D.R. 1985. Armored scales, family Diaspididae. p. 106-123. A.T. Droox, ed, In Insects of Eastern Forests. U.S. Dept. Agric. Misc. Publ. No. 1426.
23. Nakahara, S. 1982. Checklist of the armored scales (Homoptera: Diaspididae) of the conterminous United States. U.S. Dept. Agric. Animal Plant Health Insp. Serv.-Plant Protec. Quar. Publ. No. 1089.

24. Peterson, L.O.T. and R.F. DeBoo. 1969. Pine needle scale in the Prairie Provinces. Canada Dept. Fisheries and Forests Note MS-L-5.
25. Rhoades, M.H. 1986. A comparison of hosts of *Chionaspis heterophyllae* Cooley and *C. pinifoliae* (Fitch) (Coccoidea: Diaspididae) for eastern U.S. Paper abstract, Eastern Branch of Entomol. Soc. Amer., Oct. 5-8 Mtg., Philadelphia, PA.
26. Schuder, D.L. 1983. Combatting insect pests of pine trees. Purdue Univ. Coop. Ext. Serv. Publ. E-32.
27. Shour, M.H. 1986. Life history studies of the Pine Scale, *Chionaspis heterophyllae* Cooley and the Pine Needle Scale, *C. pinifoliae* (Fitch). Ph.D. dissertation, Purdue University, West Lafayette, IN.
28. Stimmel, J.R. 1978. Pine needle scale, *Chionaspis pinifoliae* (Fitch). Reg. Hortic. [Pennsyl. Dept. Agric.] 4: 15-16.
29. Takagi, S. and S. Kawai. 1967. The genera *Chionaspis* and *Pseudaulacaspis* with a criticism on *Phenacaspis* (Homoptera: Coccoidea). Insecta Matsumurana 30: 29-43.
30. Wilkey, R.F. 1977. How to make professional microslide mounts of insects and other arthropods. Pamphlet, Sargent-Welch Sci. Co., Skokie, IL.

ENVIRONMENTAL QUALITY

Chair: Peter Hippensteel
Department of Biology
Tri-State University
Angola, Indiana 46703 (219) 665-3141 ext. 276

Chair-Elect: Jack Leonard
ICFAR
611 N. Capitol
Indianapolis, Indiana 46204 (317) 262-5026

ABSTRACTS

Background Levels of Potential Toxicants in Indiana Stream and Lake Sediments. Greg R. Bright. Indiana Department of Environmental Management, Indianapolis, Indiana 46241.——Sediment monitoring is becoming increasingly important as a tool for detecting loadings of potentially toxic materials in streams and lakes. To determine whether loadings are occurring, the evaluator needs to know what the natural or "background" concentrations are. Sediment data gathered by various government agencies, universities and consultants from "background" locations (no known point sources of pollution) from across the state were assembled and computerized. Mean concentrations, range of concentrations, and standard deviations were tabulated for 21 inorganic and 13 organic constituents in background sediments. Results show that background levels in Indiana sediments are similar to those reported from Illinois. The amount of variability in naturally occurring inorganic constituents, as measured by the coefficient of variation ($s/\bar{x}$ [100]), ranged from 52% to 153%, with a mean of 98%.

The Water Quality of Northeastern Indiana Lake Inflows. Peter A. Hippensteel, Tri-State University, Angola, Indiana 46703.——The inflows of several lakes were monitored to determine the potential impact on the eutrophication of their respective lakes. Most inflows were of intermittent water quality. Both high and low flow sampling must be done to completely evaluate the magnitude of impact on each inflow. The obvious factors that influence the chemical concentrations of the inflows are the types of agricultural activity, wetland alteration, residential development, and the size and number of municipal and industrial outfalls within the watershed.

Enhancement of Phenol Biodegradation by Soil Inoculation. Russell Holland and Deborah D. Ross. Department of Biological Sciences, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——A gram positive, non-spore forming bacterium capable of growth on 0.1% phenol was isolated from soil collected from an abandoned hazardous waste landfill using the selective enrichment technique. The bacterium was then employed in experiments to determine the feasibility of using bacteria to degrade contaminants in soil. In these experiments, radiolabelled phenol was added to soil along with sufficient unlabelled phenol to bring the final concentration to 100 ppm. Biodegradation was determined by counting the radiolabelled CO_2 produced by mineralization of the phenol. The rate of biodegradation of phenol in inoculated soil was compared to the rate in uninoculated soil. It was found that the initial rate of biodegradation was faster in the inoculated soil and was initiated with a shorter lag time than in the uninoculated soil.

Creation of an Urban Acid Deposition Database. ROBERT A. PRIBUSH, PATRICIA S. MUIR, BRADLEY H. CARTER, MICHAEL J. STEVENSON AND KIMBERLY A. WADE, Department of Chemistry and the Holcomb Research Institute, Butler University, Indianapolis, Indiana 46208.——Since July, 1985, wet and dry deposition samples have been collected weekly at the Butler University Environmental Preserve (BUEP) and the samples analyzed using protocols adapted from the National Atmospheric Deposition Program (NADP). Comparison is made between NADP network data, gathered exclusively at rural sites and BUEP data, which should reflect air quality patterns in urban Indianapolis.

Noteworthy for this time period is the annual volume-weighted pH of 4.25 which showed insignificant seasonal variation and a narrow single-event range of 3.72 to 5.12. The annual pH is typical of values measured at Ohio and Illinois NADP sampling sites located directly east and west of Indianapolis. Significant anion and cation annual mean values were also typical of this region.

This detailed database provides a baseline for Indianapolis air quality with respect to acid deposition. Continuous operation of the BUEP monitoring station should provide sensitive diagnostic information regarding the impact of industrial and domestic demographic changes on the environment about Indianapolis.

A Computer Raindrop Model Used to Predict the Equilibrium of pH of Rainfall over Indianapolis. ROBERT A. PRIBUSH AND MICHAEL J. STEVENSON, Department of Chemistry and the Holcomb Research Institute, Butler University, Indianapolis, Indiana 46208. ——Understanding rainfall pH sensitivity to ambient SO_2 levels is important in establishing practical goals regarding the control of sulfur emissions. In an attempt to relate SO_2 levels to the measured pH of Indianapolis rainfall, a computer model was adapted which inputs six components expected to control the pH of rainfall: liquid water content, SO_2, CO_2, NH_3, and aerosol SO_4^{2-} (and/or NO_3^-). Relating these species to others found at equilibrium requires seventeen simultaneous equations generated from the ideal gas law, Henry's Law, the law of mass action, conservation of mass, electroneutrality, and aerosol scavenging principles. Output is in the form of graphical diagrams in which concentration of each water-soluble species is plotted vs. pH.

The theoretical pH values determined by this model were in excellent agreement with measured pH values of samples collected at the Butler University Environmental Preserve, validating the applicability of this model to the Indianapolis environment. The apparent tolerance of the pH of Indianapolis rainfall to varying SO_2 levels and meterological conditions is discussed.

Impact of Heavy Metal Pollution on Sediment Bacteria in the Maumee River. DEBORAH D. ROSS, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——River water and sediment samples were collected along a heavy metal concentration gradient in the Maumee River. Samples were analyzed for total bacterial numbers, heterotrophic activity, and numbers of bacteria resistant to Cu and Pb. Resistance was estimated by comparing CFUs on unsupplemented nutrient agar with CFUs on nutrient agar supplemented with order of magnitude increments of the heavy metals ranging from 0.001 to 1.0 mM. Both river water and sediment bacteria were more tolerant of Pb than Cu. However river water bacteria were less tolerant to both Cu and Pb than were sediment bacteria. No significant correlation was observed between heavy metal pollution at the sampling site and numbers of resistant bacteria, indicating that heavy metals are not exerting selective pressure on bacterial communities in the river.

Results of Surface Water Investigations of the Grand Calumet River/Indiana Harbor Canal Basin. JEROME RUD, HAROLD BONHOMME, GREG BRIGHT, NEIL PARKE AND JAMES STAHL, Indiana Department of Environmental Management, Indianapolis, Indiana 46241.——— As a participant in the Northwest Indiana Environmental Initiative, the Indiana Department of Environmental Management (IDEM) has been working with other governmental agencies and universities to document the current environmental conditions of the Grand Calumet River/Indiana Harbor Canal basin. This paper describes the recent water-related investigations which include water, sediment, crayfish, macroinvertebrate, and fish data from several stations on the GRC/IHC; and sediment, fish, and water (nutrients only) data from the Marquette Park Lagoons and Wolf and George Lakes (near Hammond). Crayfish were collected with a simple trap designed from coffee cans and hardware cloth. Sedimentation rates also were calculated.

Air Quality Monitoring in Southwest Indiana During the 1986 Growing Season. J.E. Simon, M. Simini, R. Grant, B. McFee and D. Reinert, Department of Horticulture, Purdue University, West Lafayette, Indiana 47907.———An air quality monitoring program begun in 1984 to determine levels of air pollutants in southwest Indiana and their impact on agricultural crops was continued and expanded during the 1986 growing season. Air pollutant levels prior to 1986 were shown to induce injury on sensitive crops. Concentrations of ozone (O_3) and sulfur dioxide (SO_2) were measured at two sites (Vincennes and Decker) and nitrogen oxides (NO_x) were measured at Vincennes. Bulk sulfate and nitrate deposition was measured at Vincennes, Decker, Patoka, and Owensville. Daily mean O_3 concentrations of 0.05 ppm to 0.08 ppm were recorded throughout the growing season. These levels have been shown to induce injury on watermelons, muskmelons, and other crops grown in the region. Ozone-type foliar injury occurred on watermelons, muskmelons and potatoes grown in this region during the 1986 growing season. Levels of SO_2 occurred during the daylight hours generally when O_3 concentrations were greatest. Measurable amounts of NO_x, which can contribute to the formation of O_3, were also present.

Summer Primary Productivity and Associated Data for Four Indiana Rivers

C. Lee Bridges, H.L. BonHomme, G.R. Bright, D.E. Clark, J.K. Ray, J.L. Rud,
J.L. Winters
Water Quality Surveillance and Standards Branch
Indiana Department of Environmental Management
Indianapolis, Indiana 46241
and
T.E. Lauer
Fisheries Section
Indiana Department of Natural Resources
Indianapolis, Indiana 46204

Introduction

In-stream dissolved oxygen concentration has, historically, been one of the cornerstones of water pollution investigations. This constituent is often the most important chemical parameter controlling the presence, diversity, and health of aquatic populations and communities. Dissolved oxygen levels in flowing waters are affected by a myriad of factors such as velocity, reaeration (1), temperature, naturally occurring and anthropogenic oxygen demanding substances, sediment oxygen demand, organismal respiration, and primary productivity. It is the last factor, primary productivity, which is the subject of this paper and we will report a variety of summertime measurements from four Indiana rivers taken by the senior authors and others no longer with the agency during the years 1981 thru 1984.

Primary productivity was only indirectly addressed in the early wasteload allocation studies of the Indiana State Board of Health (ISBH) and others. The occurrence of a prolonged very low dissolved oxygen episode in the middle Wabash River in the summer of 1977 made it apparent to the authors and others that past wasteload allocation studies did not adequately address the situation. As time progressed and computer modelling techniques evolved, industrial dischargers to the middle Wabash River (e.g., Eli Lilly Company-ELANCO Division, Weston Paper Company, and Inland Container Corporation) became very concerned with potential increased wastewater treatment costs which might adversely affect their products' viability in the competitive marketplace when the increased costs were based on decisions not utilizing the best available computer model and the associated data inputs, for the middle Wabash River. Three of the major factors potentially affecting the dissolved oxygen regimen of the middle Wabash River which had not been measured were reaeration, primary productivity and sediment oxygen demand. An interdisciplinary team of scientists, engineers, modelers, and administrators from the State of Indiana, various federal agencies, industries, universities, and an experienced consultant (*i.e.*, HydroQual, Inc.) met to design, collect, and evaluate the data necessary to reach a sound decision on the assimilative capacity of the middle Wabash River for oxygen-demanding wastes. This experience greatly shaped the approach taken with other rivers by the Indiana State Board of Health and continued by the Indiana Department of Environmental Management.

Description of Study Areas

The Wabash River is a large free-flowing river and is a major tributary of the lower Ohio River. The four sampling locations discussed in this paper are outside the area of direct influence by oxygen demanding or nutrient enriched wastewaters. The East Fork of the White River is a medium size river with numerous low-head dams and drains south central Indiana before flowing into the White River at the junction of the Knox, Daviesss and Pike Counties lines in southwest Indiana.

Trail Creek is a small river which flows into Lake Michigan at Michigan City, Indiana, a significant harbor for numerous pleasure boats and some commercial fishing tugs. The hydraulics of the mouth of Trail Creek are greatly complicated by a low gradient which results in the mixing of Trail Creek water and Lake Michigan water in a manner similar to that of an estuary. The St. Joseph River flows through Elkhart and St. Joseph Counties in northern Indiana with several hydroelectric dams which create unusual, for Indiana, diurnal river flow patterns. The water quality, effluent quality, aquatic life, flow characteristics, as well as the water quality standards and designated uses of these rivers have been recently described in other publications (2, 10, 5, 3) and will not be repeated here.

Materials and Methods

Photon flux density was measured by a LI-COR meter equipped with a submersible spherical quantum sensor. Light intensity and 1% light level was measured by Beckman Enviro-Eye. In-stream measurements of temperature, dissolved oxygen, conductivity, and pH were made with a Hydrolab Surveyor.

Primary productivity measurements were made by the oxygen method using light and dark bottles at 0.3 meter incremental depths thru the euphotic zone (4). Dissolved oxygen determinations, for primary productivity measurements, were made by the azide modification of the Winkler method (4).

In-situ and laboratory chlorophyll methods utilized a Turner Design Flourometer Model 10 instrument. *In-situ* measurements were made at the surface and at 0.3 meter interval depths to the bottom in the Wabash River. The samples for laboratory analysis were filtered and frozen in the field. These chlorophyll procedures have been previously described in detail (4). Whole water samples were collected and preserved with formalin for plankton analysis. The samples were later enumerated and identified to major taxonomic groups in a Sedgwick-Rafter counting cell (4).

Results and Discussion

Figure 1 illustrates the correlation of *in-situ* chlorophyll measurements with laboratory results in 1981 samples from the Wabash River where chlorophyll *a* concentration ranged from 20 to 60 ug/1. The correlation coefficient was 0.923 in the range studied. Figure 2 illustrates the correlation of *in-situ* measurements of chlorophyll *a* with laboratory results from Wabash River samples in 1982 where chlorophyll *a* concentration ranged from 50 to 150 ug/1 and had a correlation coefficient of 0.868. These findings were similar to those previously reported at lower concentrations with marine phytoplankton (6, 7, 9). The *in-situ* technique was very useful in demonstrating the cross-sectional and depth distribution of the phytoplankton over a long stretch of river.

The chlorophyll *a* concentrations at different depths as well as physical and chemical data for three stations on the Wabash River are shown in Table 1. It was apparent from these and many other similar measurements that the Wabash River was well mixed for physical, chemical and phytoplankton components during summer low flow conditions from surface to bottom and from bank-to-bank when you were not in the immediate vicinity of mixing zones.

Table 2 lists the chlorophyll *a*, pheophytin *a*, primary productivities and phytoplankton cell counts data for the four rivers. Only four locations on the Wabash River are included in this paper but these sites are representative of the upper, middle and lower sections of the over one hundred and fifty miles of study area outside the areas of direct influence of effluent and tributary mixing zones.

It should be noted that the middle Wabash River can routinely generate a significant amount of net primary production (*i.e.*, 400 to 784.1 mg C/m^2/hr) under summer-

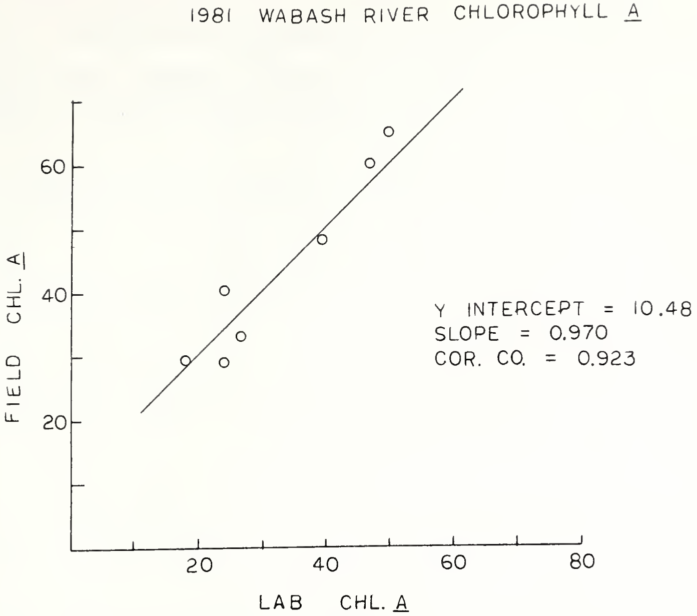


FIGURE 1. Correlation of *in-situ* measurements of Chlorophyll *a* with laboratory determinations for middle Wabash River samples in 1981.

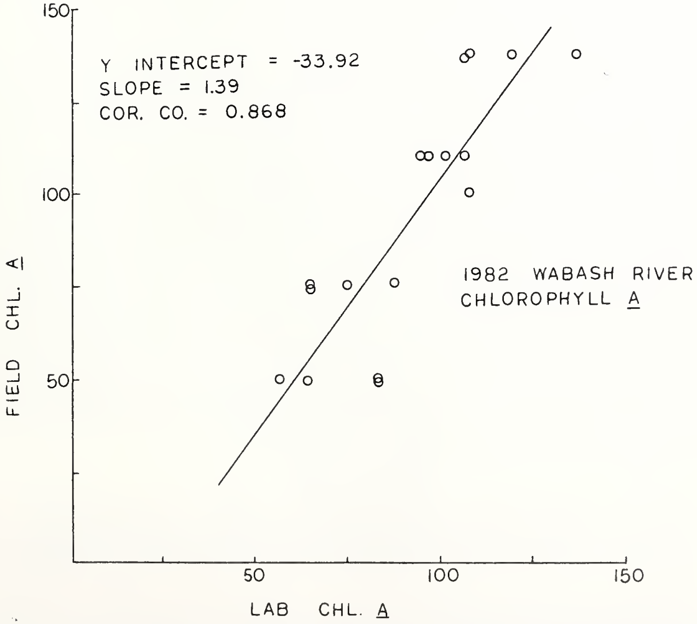


FIGURE 2. Correlation of *in-situ* measurements of chlorophyll *a* with laboratory determinations for middle Wabash River samples in 1982.

TABLE 1. Physical and chemical data collected at various depths from the center of the channel in the Wabash River during primary productivity investigations.

Location	Date	Depth Meters	Photon Flux Density uE/cm^2/sec	Temperature °C	Dissolved Oxygen mg/1	Conductivity uS/cm (umhos/cm)	pH S.U.	In-situ Chlorophyll *a* ug/1
Lafayette: Mascouten Park	8/11/81	Surface	1,050	23	9.0	580	8.2	47.0
		0.5	265	23	8.9	575	8.2	50.0
	8/3/82	Surface	1,150	27	10.2	722	7.6	76.0
		0.3	355	26	9.8	727	7.8	78.0
		0.6	95	26	9.5	735	7.8	78.0
		0.9	31	26	9.4	733	7.8	79.0
Montezuma: Boat Ramp	8/13/81	Surface	600	25	7.5	605	8.2	19.0
		0.15	35	24	7.5	605	8.2	19.0
Just Below Manhattan Island	9/11/82	Surface	1,500	25	7.7	810	7.3	55.0
		0.3	340	25	7.7	813	7.3	58.0
		0.6	23	25	7.7	817	7.3	59.0
		0.9	15	25	7.7	819	7.3	59.0
		1.0	2.4	25	7.7	821	7.3	60.0
		1.2	0.2	25	7.7	821	7.3	—
Terre Haute: West Ramp (U.S. 40)	8/20/81	Surface	700	22.5	9.3	605	8.0	55.0
		0.5	520	—	—	—	—	57.0
		1.0	1.2	—	—	—	—	57.0
		1.5	—	22.5	9.3	600	8.0	59.0
	8/19/82	Surface	1,000.0	28.0	10.0	—	—	27.0
		0.3	310.0	—	9.8	—	—	28.0
		0.6	20.0	—	9.9	—	—	28.0
		0.9	6.0	—	—	—	—	—
		1.0	—	—	9.9	—	—	28.0

time conditions. On August 30 and August 31, 1984, measurements were made at three locations in the vicinity of the Cayuga Generating Station (G.S.) and the confluence of Mill Creek and are shown in Table 3. The station upstream of the Cayuga G.S. had primary production rates higher than any ever measured during previous investigations by this office. The other high values for primary production, chlorophyll and phytoplankton densities (Tables 2 and 3) are quite comparable to those reported for the Thames River (8) or a eutrophic lake (11). The other two sampling locations were in the vicinity of the stretch of river where serious dissolved oxygen depletion had been observed in the past.

The East Fork of the White River, Trail Creek, and the Saint Joseph River have lower chlorophyll *a* concentrations, primary productivity rates and phytoplankton densities in comparison to the middle Wabash River. All three of these smaller rivers also receive municipal and industrial effluents but never generate the same level of planktonic densities, chlorophyll *a* concentration or planktonic primary production rates. It should also be noted that none of the rivers in the locations studied, including the Wabash, had any significant amount of periphyton or macrophytes.

Literature Cited

1. Crawford, Charles G. 1985. Determination of reaeration rate coefficients of the Wabash River by the modified tracer technique. U.S. Gea. Surv., Water Res. Inv. 85-4290.
2. Gammon, J.R. and J.M. Reidy 1981. The role of tributaries during an episode of low dissolved oxygen in the Wabash River, Indiana. Am. Fish. Soc., Warmwater Streams Symposium, 1981, pp 397-407.

TABLE 2. Chlorophyll *a*, primary productivity, and algal cell count data from four Indiana rivers. (Locations are listed upstream first for each river). Values are mean values for the euphotic zone.

River	Location	Date	Depth Meters	Chlorophyll *a* ug/1	Pheophytin *a* ug/1	Primary Productivity Gross mgC/m²/hr	Primary Productivity Net mgC/m²/hr	Phytoplankton Cells/m1
Wabash River	Lafayette-Mascoutten Pk.	8/11/81	0-1.0	66.0	6.2	449.0	341.0	—
		8/3/82	0-1.2	76.2	26.6	663.0	469.0	66,254
		9/13/83	0-0.7	141.4	35.5	444.6	400.0	72,534
Wabash River	Montezuma-boat ramp	8/13/81	0-0.5	18.4	11.0	82.0	91.0	—
		8/18/81	0-0.3	18.4	9.3	129.0	124.0	—
		8/17/82	0-1.0	114.2	51.2	680.0	674.0	74,712
		9/14/83	0-1.0	160.7	29.1	766.4	705.2	32,446
		9/20/83	0-0.7	80.9	13.6	177.2	157.2	19,140
Wabash River	Terre Haute-U.S. 40 bridge	8/18/81	0-1.0	21.1	6.5	70.0	—	—
	U.S. 40 bridge	8/20/81	0-1.0	53.8	9.6	403.0	256.0	—
	U.S. 40 bridge	8/19/82	0-1.0	120.2	50.0	789.0	663.0	119,750
	S.R. 63 bridge	9/15/83	0-0.7	191.2	20.7	444.6	400.0	55,840
	1-70 bridge	9/15/83	0-0.9	247.0	23.7	847.5	784.1	60,027
Wabash River	Merom	8/20/81	0-0.2	22.9	10.8	—	—	—
		8/19/82	0-0.8	132.5	70.0	738.0	613.0	125,981
East Fork of White River	Above Columbus STP	7/12/83	0-0.9	30.1	7.8	181.0	87.0	6,435
	Above Columbus STP	7/14/83	0-1.2	—	—	160.0	160.0	9,570
	Above Columbus STP	8/9/83	0-1.2	—	—	39.0	69.0	5,544
	Below Haw Creek	7/12/83	0-1.1	128.9	2.4	163.0	163.0	6,369
	Below Clifty Creek	7/12/83	0-1.5	17.8	2.9	183.0	183.0	7,738
	Azalia	8/9/83	0-1.0	24.7	9.8	181.0	138.0	2.310
Trail Creek	0.25 mile upstream of STP	6/28/83	0-1.0	5.57	4.68	28.94	—	—
	0.25 mile upstream of STP	8/4/83		7.44	2.78	—	—	1,254
	E Street bridge	6/28/83	0-1.0	3.73	3.04	12.86	—	NA
	E Street bridge	8/4/83	0-2.0	4.61	2.43	14.65	12.52	1,023
	Naval Reserve Armory	6/28/83	0-2.1	10.65	0.82	78.01	—	—
St. Joseph River	Bristol	7/30/83	0-2.0	5.6	4.7	28.9	—	—
	C.R. 17	7/30/83	0-1.4	17.4	12.4	128.0	114.0	19,503
	Elkhart Dam	7/30/83	0-1.4	20.8	9.9	270.0	229.0	14,765
	Sherman Street	8/1/83	0-1.0	20.7	9.1	228.0	144.0	14,438
	State Route 219 Bridge	8/6/83	0-1.8	30.1	12.5	184.0	108.0	12,375
	1 and M Dam	8/6/83	0-1.8	29.2	14.2	403.0	367.0	11,781
	Mishawaka Avenue	8/6/83	0-2.1	28.7	14.6	253.0	218.0	9,554
	Twyckenham Bridge	8/6/83	0-2.2	21.9	13.6	309.0	271.0	4,595
	Below Kayak Run	8/8/83	0-1.8	NA	NA	485.0	436.0	12,556
	St. Patrick's City Park	8/8/83	0-1.2	33.2	17.1	428.0	320.0	16,004

TABLE 3. Primary productivity and chemical data collected from the Wabash River on August 30, 31 1984, in the vicinities of Cayuga and Montezuma, Indiana (Vermillion County).

Location	Primary Productivity mgC/m²/hr Gross	Net	Alkalinity Total $CaCO_3$ mg/l	Hardness $CaCO_3$ mg/l	Total Organic Carbon mg/l	Dissolved Oxygen mg/l
Upstream of Cayuga Generating Station	1,144.0	1,226.0	160.	250.	8.6	12.5
At confluence with Mill Creek	733.0	543.0	150.	250.	8.5	14.1
At confluence with Sugar Creek	656.0	574.0	150.	220.	7.2	6.4

3. Indiana Department of Environmental Management, 1986. 1984-85 305(b) Report.
4. Indiana State Board of Health, 1982. Field and Laboratory Procedures Manual - Division of Water Pollution Control.
5. Indiana State Board of Health (1984). 1982-83 305(b) Report.
6. Kiefer. D.A. 1973a. Fluorescence properties of natural phytoplankton populations, Marine Biology, 22, 263-269.
7. Kiefer, D.A. 1973b. Chlorophyll *a* fluorescence in marine centric diatoms: responses of chloroplasts to light and nutrient stress. Marine Biology, 23, 39-46.
8. Kowalczewski A., and T.J. Lack, 1971. Primary production and respiration of the phytoplankton of the River Thames and Kennet at Reading. Freshwater Biology, 1, 197-212.
9. Lorenzen, C.J. 1966. A method for the continuous measurement of *in-vivo* chlorophyll *a* concentration. Deep Sea Research, 13, 223-227.
10. State of Indiana, 1980. The Indiana Water Resource. G. Douglas Clark, Editor. 508 pp.
11. Wetzel, R.G. 1975. Limology, W.B. Saunders Company, Philadelphia. 743 pp.

GEOLOGY AND GEOGRAPHY

Chair: Akhtar Husain Siddiqi
Department of Geography and Geology
Indiana State University
Terre Haute, Indiana 47809 (812) 237-2258

Chair-Elect: Konrad J. Banaszak
U.S. Geological Survey
Water Resources Division
6023 Guion Rd., Suite 201
Indianapolis, Indiana 46254 (317) 927-8640

ABSTRACTS

Ground-water Modeling of Small Watersheds in the Coal-mining Region of Southwestern Indiana. Richard F. Duwelius, U.S. Geological Survey, Water Resources Division, Indianapolis, Indiana 46254.——Ground-water flow in four small watersheds in southwestern Indiana was simulated using a modular finite-difference model as part of a coal hydrology study done by the U.S. Geological Survey. One reclaimed mine, one unreclaimed mine, and two unmined agricultural areas were modeled. Model layers were constructed to simulate flow in the entire sequence of rocks between hydraulically "tight" underclays beneath major coal seams.

The models confirm the low hydraulic conductivities of the unconsolidated glacial till and Pennsylvanian bedrock. Calibrated conductivity values, which are higher than field-measured values, indicate preferential flow in areas of higher transmissivity or along fractures and bedding planes not intersected by the test wells. Underclays separate flow systems in each watershed. Shallow flow systems discharge to smaller streams while flow in the deeper bedrock follows regional patterns and discharges to major surface drains, such as the Wabash and Eel Rivers. The models indicate that coal mining can triple recharge rates and horizontal and vertical conductivities, deepen flow paths, and alter surface drainage within small watersheds.

Sulfur Isotope Ratios in Indiana Sulfide Minerals. W.S. Gaddis and N.R. Shaffer, Indiana Geological Survey, Bloomington, Indiana 47405.——Sulfur isotope ratios were determined for more than 100 secondary Mississippi Valley-type sulfides collected from geodes, vugs, and joints in Mississippian, Devonian, and Silurian carbonate rocks throughout Indiana to understand the origin of the sulfur. One possible origin of the sulfides is that hydrothermal water containing sulfur with $\delta^{34}S$ of 0°/oo rose through faults such as the Mt. Carmel Fault, permeated carbonate formations, and deposited secondary sulfide minerals. If true, then sulfides in geodes and joints near the fault system should have sulfur ratios near 0°/oo, and values should change away from the fault as the hydrothermal water interacted with ground water with positive $\delta^{34}S$ values.

Sulfur isotope values range from +29.8 to −26.5°/oo (average −4.6°/oo) but do not show patterns associated with faults. Sulfur in pyrite (average +4.3°/oo) and in sphalerite from joint fills (average +6.9°/oo) tend to have more positive isotope ratios. From this evidence it seems unlikely that faults and fractures were pathways for hydrothermal sulfur-bearing fluids.

Examination of a Popular Belief: Is There a Relationship Between Winter and Summer Temperatures? WILLIAM A. GUSTIN, ISU Climatology Laboratory, Department of Geography/Geology, Indiana State University, Terre Haute, Indiana 47809.——In order to examine the widely-held notion that the weather of one season is a predictor of the next, monthly average temperature data were used to establish 30-year normal values for the Terre Haute 8S reporting station. The period of December through February was classified as being the 'winter' season, and that of June through August represented the 'summer' season. An attempt was made to ascertain the strength of the relationship between summer and winter temperatures, if any existed. First, the relationship of a preceding summer to the temperatures of the following winter were analyzed. Likewise, the relationship of the temperatures of a preceding winter season was analyzed in respect to its efect on a following summer season. These analyses were accomplished by calculating the monthly and seasonal derivations from the calculated 30-year normals. The deviations were used to determine 'r' values, which show the degree of correlation between an independent and a dependent variable. Initial tests of the data indicate a low degree of correlation, although some data subsets show some stronger elements of correlation.

An Estimate of Indiana's Coal Reserves that Comply with Current Sulfur Dioxide Emission Standards. WALTER A. HASENMUELLER, LOUIS V. MILLER AND JIMMY J. JOHNSON, Indiana Geological Survey, Bloomington, Indiana 47405.——Current clean-air standards limit emissions from coal-fired electric utilities to a maximum of 1.2 pounds of sulfur dioxide per million Btu heat input. We selected the 920 complete channel samples of Indiana coal seams with known reserves from the Indiana Geological Survey's Coal Analysis Data Base to compute the pounds of sulfur dioxide per million Btu for each of these samples. The computed values of pounds of sulfur dioxide per million Btu have a range of 34.0 pounds and a mean of 5.6 pounds; 4.2 percent of the computed values are at or below the 1.2-pound standard. We used recent reserve estimates to weight each computed value with the fraction of the total Indiana reserve that it represents. These weighted values were then used to construct a cumulative curve of pounds of sulfur dioxide per million Btu versus total coal reserves. The curve indicates that about 461 million tons, or 2.8 percent of Indiana's 17.5 billion tons of coal reserves, are at or below the 1.2-pound standard.

New Reef Structures in Daviess County, Indiana

Roger F. Boneham
Department of Geology
Indiana University at Kokomo
Kokomo, Indiana 46902
and
Thomas E. Kesler
Purdue University Computing Center
West Lafayette, Indiana 47907

Introduction

There are two broad areas of reef development crossing the state (1). The northernmost one is called the Fort Wayne Reef Bank. It sweeps across the northern counties from Lake to Adams with an average width of approximately 30 miles. It forms a broad shelf which outlines the southern flank of the Michigan Basin.

Many of the reefs in the Fort Wayne Reef Bank are exposed in quarries and occasionally in road cuts. The accessability of these northern structures has greatly aided in our understanding of their formation (3,4,7,9,10). The individual reefs that make up this Bank are relatively small structures. Generally, they are less than one square mile in area with a few notable exceptions. The small structures have been variously classified as pinnacle reefs, biohermal mounds or patch reefs. The reefs occur in Silurian age rocks but the overlying formations are often bowed upward and sometimes thin as they pass over the central part of the structural high.

The study we have undertaken centers upon the southern belt of reefs in southwestern Indiana called the Terre Haute Reef Bank. They outline the eastern edge of the Illinois Basin and are not exposed at the surface. They run in a 25-mile-wide belt from the Ohio River area of Spencer County northwesterly to the Indiana-Illinois state boundary in Vermillion County (1). Previous studies from Indiana and Illinois (2,11,12) have shown that subsurface structure maps and isopach maps can locate reefs.

A good example of this is Noel's study of the Plummer Field (8). His structure maps drawn on tops of Renault Formation, Salem Limestone, and Middle Devonian Limestone clearly illustrate the underlying reef. His isopach maps of the Ste. Genevieve Limestone, Salem Limestone, and New Albany Shale indicates a thinning of these beds as they pass over the reef core.

Discussion

We decided that it should be possible to find undiscovered reefs by drawing structure maps and isopach maps on various formations in the five county area of Clay, Vigo, Sullivan, Greene, and Daviess Counties. We were also aware that a number of other geologists have already done such structure maps since this is an area of oil exploration.

We acquired a database of approximately 3,300 well logs from Scout Check of Evansville. The information each well log contains such as well location, oil production and formation tops is now stored in our program. We used INDIMAP, a program maintained by the Indiana Geological Survey, to change all the well locations to Lambert Coordinates for ease of plotting the well sites. We then proceeded to write a program to draw structure maps and isopach maps from information in our well database using the DI-3000 Contouring package produced by Precision Visuals.

In order to test the program, we chose those localities which contained known reef structures. We produced subsurface contour maps and isopach maps of each of the following strata: Barlow Limestone, Upper Paint Creek Limestone, Lower Paint Creek Formation, Upper Renault Formation, Lower Renault Formation, Aux Vases Formation, Ste. Genevieve Limestone, Salem Limestone, and New Albany Shale. Not all of these formations were present in each of our wells but generally enough information was available to produce usable maps from a number of rock formations. We used the premise that two or more formations had to show a structural high in the same locality before we assumed there was an underlying reef.

The program clearly located the following reefs from subsurface structure maps: Marts, Plummer, Riley South, Prairie Creek, Terre Haute South, and Fairbanks. It did not locate the following reefs: Blackhawk, Cory, Riley, and Staunton. We believe the program is useful since it located most of the reefs that cover areas greater than 250 acres.

Summary

We have located thirteen new subsurface structures on the Terre Haute Reef Bank of southwestern Indiana that have the characteristics of previously discovered pinnacle reefs. These are scattered over a five-county area but eight of them are concentrated in Daviess County. Most cover areas ranging between 200-600 acres. There are no obvious surface indications of these structures but subsurface structure maps indicate doming of some formations and, in a few cases, isopach maps indicate formation thinning over some of the structures.

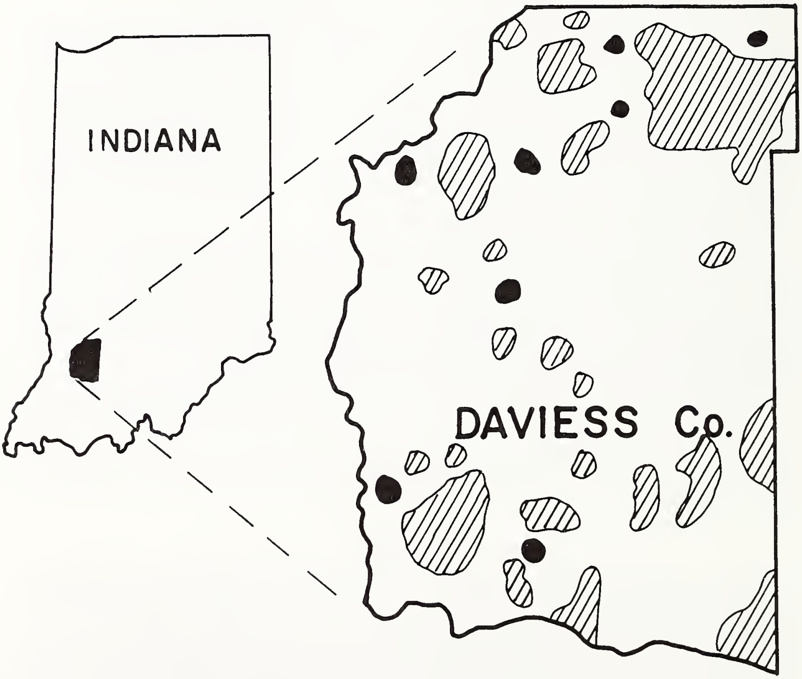


FIGURE 1. Reef structures in Daviess County. Lined areas are known reefs. Black areas are new reefs found in this study.

Acknowledgments

We wish to acknowledge the following grants provided by Indiana University which defrayed part of the cost of this research.

Grant-in Aid of Research No. 22-631-07, 1983.
Grant-in Aid of Research No. 22-631-08, 1986.

Literature Cited

1. Ault, C.H. and others. 1976. Map of Indiana showing thickness of Silurian rocks and location of reefs and reef-induced structures. Indiana. Geol. Surv. Misc. Map 22. Bloomington, Indiana.
2. Bristol, H.M. 1974. Silurian pinnacle reefs and related oil production in southern Illinois. Illinois. Geol. Surv. Illinois Petroleum 102: 98p.
3. Carozzi, A.V. and V.E. Zadnik. 1959. Microfacies of Wabash reef, Wabash, Indiana. Jour. Sed. Petrol. 29:164-171.
4. ______. and J.B. Hunt. 1960. Fore-reef petrography of the Silurian Rich Valley reef, Indiana Jour. Sed. Petrol. 30:209-217.
5. Carpenter, G.L. and S.J. Keller. 1985. Oil development and production in Indiana during 1984. Indiana. Geol. Surv. Mineral Con. Sr. 31: 53p.
6. Droste, J.B. and R.H. Shaver. 1980. Recognition of buried Silurian reefs in southwestern Indina: Application to the Terre Haute Bank. Jour. Geol. 88:567-587.
7. Erdtmann, B. and D.R. Prezbindowski. 1974. Niagaran (Middle Silurian) interreef fossil burial environments in Indiana. N. Jahrb. Geol. Palaeont. Abh. 144:342-372.
8. Noel, J.A. 1979. The Plummer Field, Greene County, Indiana. Indiana. Geol. Surv. Spec. Rpt. 17: 24p.
9. Shaver, R.H. 1974. Silurian reefs of northern Indiana: Reef and interreef macrofaunas. Amer. Assoc. Petroleum Geol. Bull. 58:934-956.
10. ______. 1980. Stratigraphy, structure and zonation of large Silurian reef at Delphi, Indiana. Amer. Assoc. Petroleum Geol. Bull. 64:115-131.
11. Smoot, T.W. 1958. Relation of Silurian reefs to Ordovician structure in the Patoka oil area. Illinois. Geol. Surv. Cir. 158: 20p.
12. Stevenson, D.L. 1973. The effect of buried Niagaran reefs on overlying strata in southwestern Illinois. Illinois. Geol. Surv. Circular 482: 22p.

Neuropteris Ovata in Lacustrine Facies Sequence below Raben Branch Member (Patoka FM.) at St. Wendel, Indiana and Related Carboniferous Reconnoissance Investigations

Garre A. Conner
Paleobotany Laboratory
Departments of Geology and Biology
Indiana University
Bloomington, Indiana 47405

Coal, Flora and Carboniferous Strata in Posey County, Indiana 1837-1937, Reconnoissance Investigations

Efforts to describe the Pennsylvanian age coal floras of Posey County were initiated simultaneously with the European's early descriptions of their Carboniferous floras. Most of the early research was written by Continental and British naturalists. F.B. Schlotheim (1804), E.T. Artis (1833), J. Lindley and W. Hutton (1831), and H.T. Witham (1833) produced some of the earlier monographs describing the coal floras. "Histoire des Vegetaux Fossiles," by A. Brongniart (1828) became perhaps the most significant of these monographs to influence the development of early Amerian coal flora classifications. Professor Leo Lesquereux published the first extensive account of North American coal floras (1878-1880) in which Brongniart's division fo the genus *Neuropteris*, "*Nevropteris*" into species was strongly disputed. Lesquereux having not seen the European type specimens erroneously identified many new species of *Neuropteris*; although this event inspired later insight into the natural groupings of pinnule forms and weaknesses of the form genera convention used for foliage classification. Authors have resolved some of the ambiguity created by Lesquereux while others have further added to it. Investigation of the Raben Branch coal flora is based on pinnule form and vennation pattern.

Traditionally investigations of the coal floras described the locations and general stratal horizons where the floras were found. Classical Nineteenth Century concepts in dynamical and historical geology, foundations of today's discipline, which evolved from the institutions of British and Continental geologists were soon imparted to North America by David Dale Owen, M.D. and gentlemen colleagues at New Harmony, Indiana. In conformity to an order of the Indiana Legislature, David Dale Owen, M.D., State Geologist conducted a geological reconnaissance of the state of Indiana in 1837, (Owen, D. 1859, p. 5-8) in which a description of Posey County included the ridge between Big Creek and the Ohio River and the "Succession" in the hills at the New Harmony "Cutoff" along the Wabash River.

D.D. Owen (1859, Second Part. p. 14) in a continuation of report presented a table illustrating the chronological succession of sedimentary or aqueous rocks including the Coal Measures. Also included in the report Coal Measures of Indiana, written by Prof. Leo Lesquereux (1859, Second part. p. 296) were references to coal floras at Big Creek, Blairsville, and Rush Creek. A translation of A. Brongniart's classification for foliage in the coal floras was included (Lesquereux, L. 1859, Second Part. p. 352).

Following his geological reconnaissance of the State of Indiana in 1837, David Dale Owen was appointed United States Geologist, and the Headquarters of the United States Geological Survey was located in New Harmony for the proceeding seventeen years (Wilson, W. 1964. p. 199).

David Owen (1843, p. 336-337) described lycopod trunks from Posey County as "fossil palm trees." Sir Charles Lyell (1849, p. 272) and D.D. Owen described "an upright Sigillarian tree" and growth floor in shale which they excavated on the ridge near Blairsville (Figure 1). D.D. Owen (1856) acting as Principal Geologist for the Commonweath of

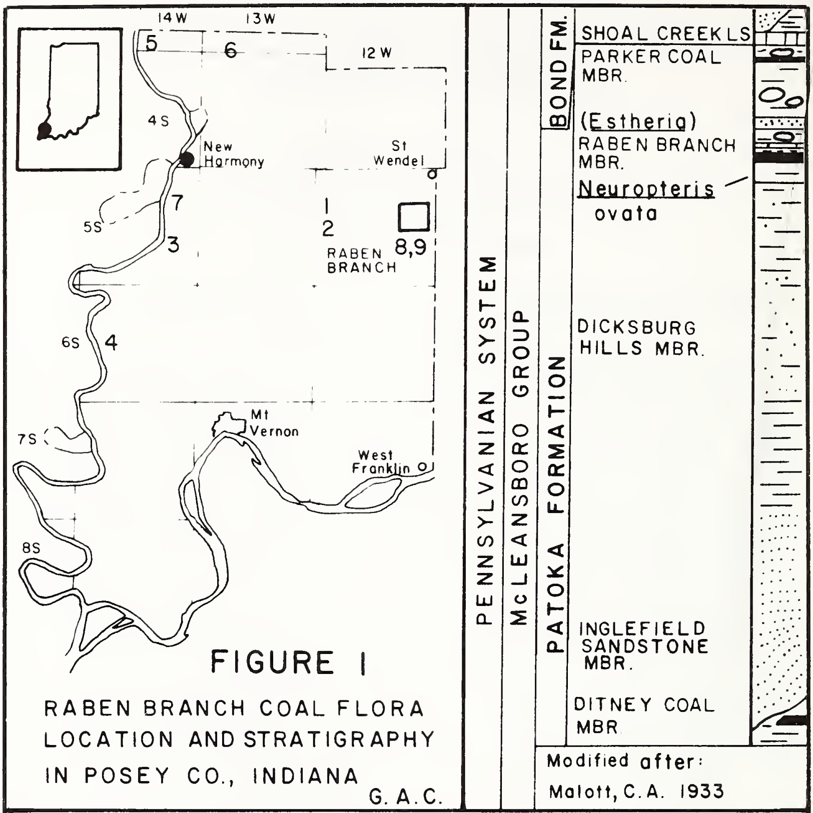


FIGURE 1

RABEN BRANCH COAL FLORA LOCATION AND STRATIGRAPHY IN POSEY CO., INDIANA G. A. C.

1. Fossil palm trees. D. D. Owen (1843)
2. Coal floras. C. Lyell (1849)
3. Rush Creek. L. Lesquereux (1862)
4. Big Creek. L. Lesquereux (1862)
5. Grayville Bluff. L. Lesquereux (1862)
6. Mumford Hills. L. Lesquereux (1862)
7. Cuttoff. J. Sampson collection.
8. Locality 39. W. J. Jongmans (1937) *Neuropteris* ovata at Raben Branch.
9. Coal balls. J. Hall (1952)

Kentucky reported on a geological survey in Kentucky made in the years 1854-1855. The Carthage Limestone (Parker Limestone Indiana equivalent) across the Ohio River (1856, p. 60). D.D. Owen (1856, p. 537) included a Paleontological Report of the Fossil Flora of Coal Measures of the Western Kentucky Coal Field by L. Lesquereux. *Neuropteris* flexuosa and *Neuropteris* tenuifolia were described from strata associated with the No. 5 coal at the Mulford mines in Union County, Kentucky.

Colonel Richard Dale Owen, M.D. State Geologist (1862) published a report of a Geological Reconnaissance of Indiana made during 1859 and 1860 by D.D. Owen. Included was a Report on the Distribution of the Geological Strata in the Coal Measures of Indiana (1862, p. 292-296) by Prof. L. Lesquereux describing coal floras at outcrops in Posey County at Rush Creek near its entry to the Wabash River two miles south of New Harmony. *Neuropteris* hirsuta and *Pecopteris* polymorphia were abundant there.

L. Lesquereux and A.H. Worthen (1866, v. 2. p. 429) refer to *Pecopteris* and *Neuropteris* from Murphysboro, Illinois that were collected by Mr. James Sampson of New Harmony.

E.T. Cox (1876, p. 251) referred to "the Merom sandstone" of former reports ranging through Indiana from Sullivan through Vanderburgh and Posey Counties.

J. Collett (1884, p. 64-65) reported on the status of coal floras collecting at Rush Creek which by then had been sufficiently extensive to cause the permanent inundation of the out-crop. The coal flora there was abundant and well preserved, although the matrix underclay when excavated from under the water deteriorated quickly as it dried. Specimens from Rush Creek were soon displayed in the cabinets of gentlemen collectors throughout the world. The extensive collections of Mr. James Sampson from the Rush Creek location are displayed at the Workingmen's Institute in New Harmony, founded in 1838 by William Maclure, as well as his collections from the New Harmony "Cutoff" and the equivalent strata exposed at Grayville, Illinois along the Wabash River.

Through the turning of the Century D.D. Owen's and R.D. Owen's successors in the Indiana Geological Survey focused on a more intense reconnaissance dividing and naming the stratal formations and describing the Indiana physiography. The newer stratigraphic divisions for the Carboniferous strata and physiographic descriptions for Posey County and adjacent areas appeared in the Patoka Quadrangle: U.S.G.S. Atlas Folio No. 105, prepared by M.L. Fuller and F.G. Clapp (1904). Their columnar section illustrated the Ditney formation, Inglefield formation, and the Wabash formation with the Parker coal at its base; in succession within the Carboniferous System.

Numerous subsurface borings for coal, brine, and other minerals in southwestern Indiana, recorded during Owen's tenure, revealed the general basin structure and the Patoka Quadrangle Atlas listed reference elevations. One of the earliest detailed structural maps in the area was drawn from an altimeter survey by R.R. Schrock and C.A. Malott (1929, p. 1302-1304) based on the West Franklin Limestone Formation. Malott (1922, p. 59-256) named the Wabash Lowland physiographic division and described the valley features.

Embellishing the descriptions of the glacial features and deposits in the Wabash Valley of Southwestern Indiana found in the previously cited works. M.M. Fidlar (1933) described the "hills of circumalluviation" in the region. This physiographic feature consists of areas of bedrock hills in the Merom sandstone overlying the West Franklin Limestone which are buried or nearly covered with Quaternary age unconsolidated loess and sands.

C.A. Malott (1933) compiled a structure map of the St. Wendels area in Vanderburgh and Posey Counties Indiana based on the *Estheria* zone and coal streak below the Parker Coal formation. These outcrops (Figure 2) were traced through the headland tributaries of Big Creek including Raben Branch, Clair Creek, and Luigs Creek where structural closures have defined several commercial oil fields.

W.J. Jongmans (1937, p. 417-422) remarked on specimens of *Neuropteris* ovata in the American Carboniferous stating this as an indicator for the Westphalian D unit of Saar-Lorraine basin and illustrated several specimens from "Location 39" one-half mile south of St. Wendel. Other genera and species including *Pecopteris* proliferatus were stated to mark the upward transition to the lower Stephanian.

C.A. Malott (1939) named the Hazelton Bridge Formation in Gibson County and surrounding area. The Hazelton Bridge Formation succeeds the Inglefield sandstone and lies below the massive portion of the Dicksburg Hills sandstone (Malott, C.A. 1947) exposed in the bedrock hills of Posey County and adjacent area in southwestern Indiana.

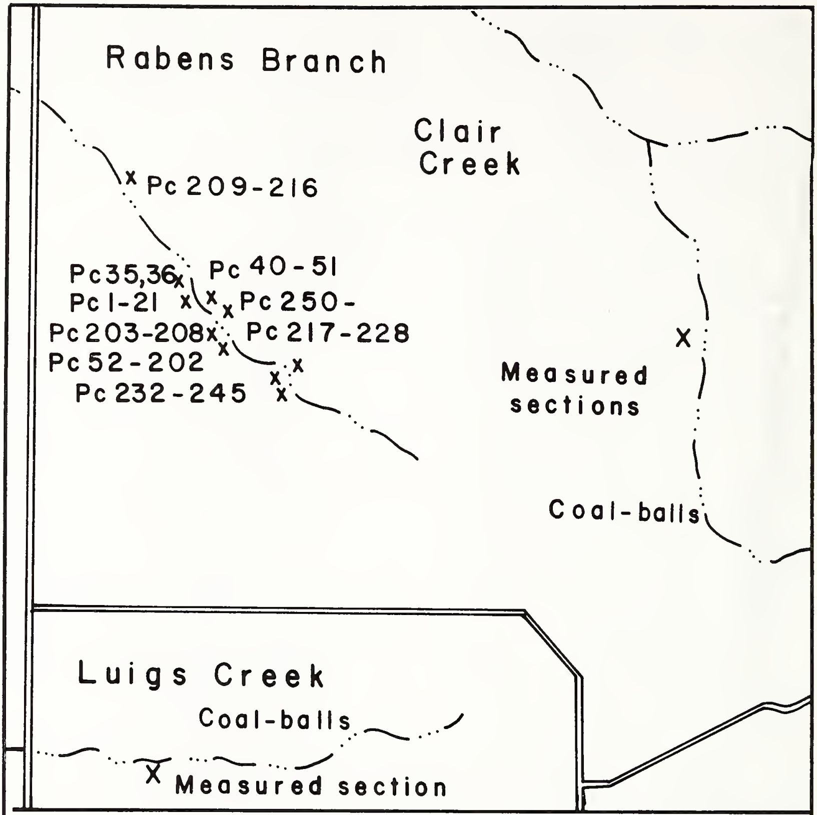
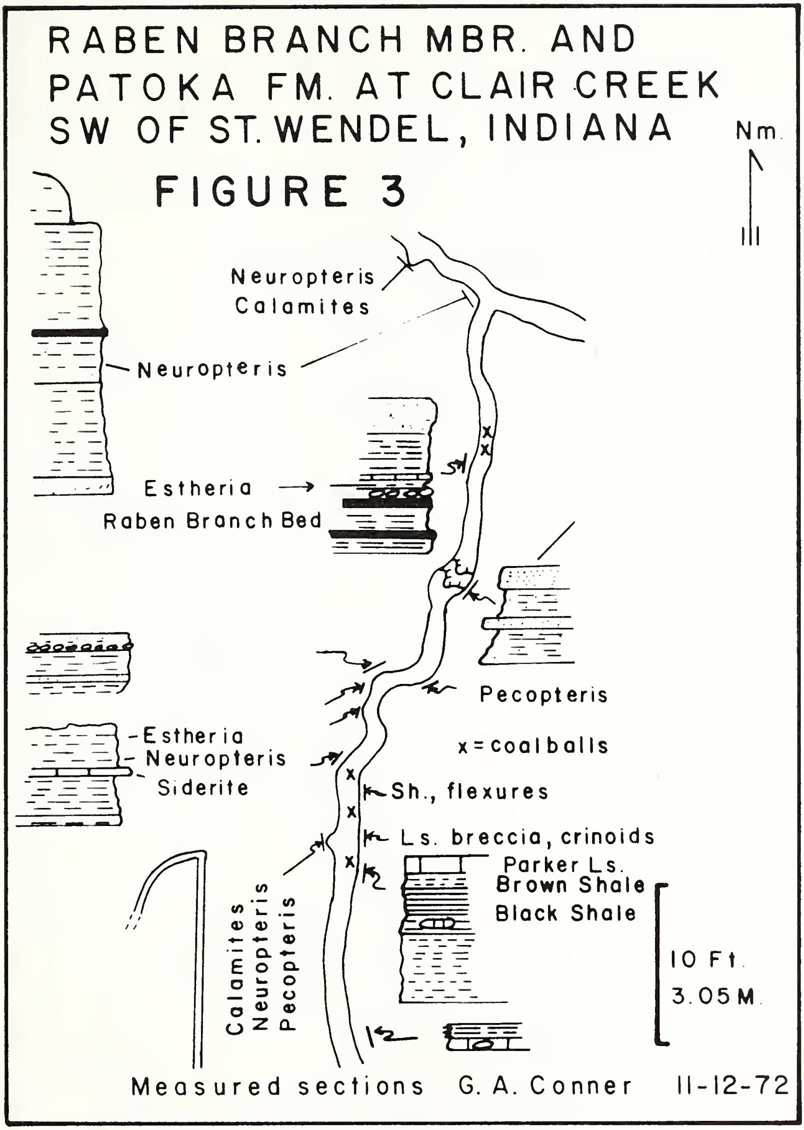


Figure 2. Raben Branch area SW of St. Wendel in Posey Co., Indiana

The Raben Branch bed within the Parkers Formation was named by C. Malott (1947, p. 131-132) including a thin coal streak four or six cm. thick, overlain by a ferrous carbonate band less than two cm. thick and containing *Estheria* exposed at Raben Branch the type section. Further this bed is located approximately six meters below the Parkers Coal and black shale overlain by the Parker Limestone (Carthage Limestone of Kentucky or Shoal Creek Limestone of Illinois). The stratigraphic column in (Figure 1) is essentially from Malott's unpublished contour map. J.W. Hall (1952, p. 763-768) described phloem cells in *Heterangium* americanum from a coal ball petrifaction at an exposure near St. Wendel, Indiana. This locality appears to be along the channel of Clair Creek east of Raben Branch (Figure 2).

Stratal succession of coal floras in a Constructional Deltaic and Lacustrine Sequence associated with the Raben Branch Member

Coal flora was collected from Luig Creek (Figure 3), Clair Creek (Figure 4), and Raben Branch in 1967 recording the stratal position of genera in a seven meter interval

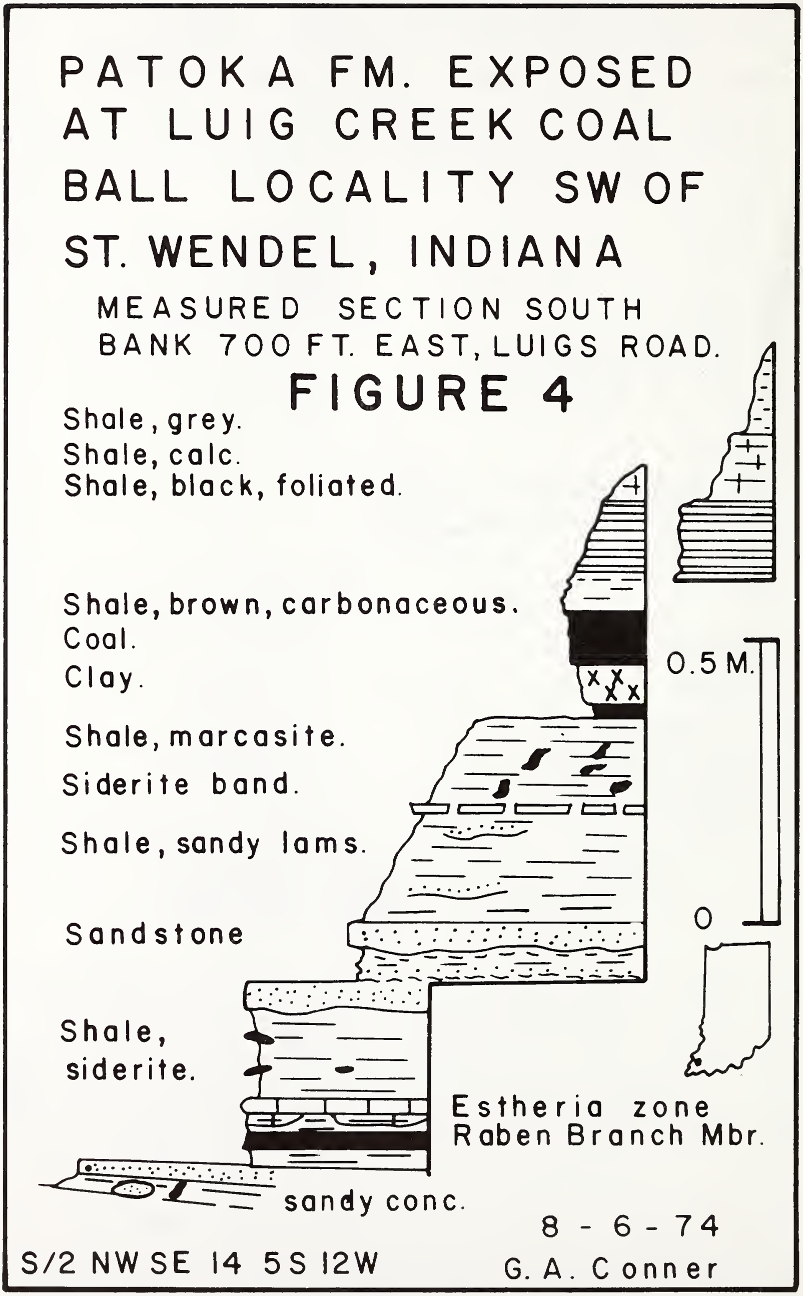


RABEN BRANCH MBR. AND PATOKA FM. AT CLAIR CREEK SW OF ST. WENDEL, INDIANA

FIGURE 3

Measured sections G. A. Conner 11-12-72

between the Parker Coal and the upper Dicksburg Hills sandstone. Collections from Raben Branch included five cubic meters of shale from in-situ excavations one to three meters long, one-half to one meter wide, and less than one meter in stratal depth. The entire stratigraphic interval ranges one meter above to one meter below the Raben Branch Bed. Allochthonous flora is preserved as carbon compressions lying parallel to stratification revealing no evidence of a growth floor.

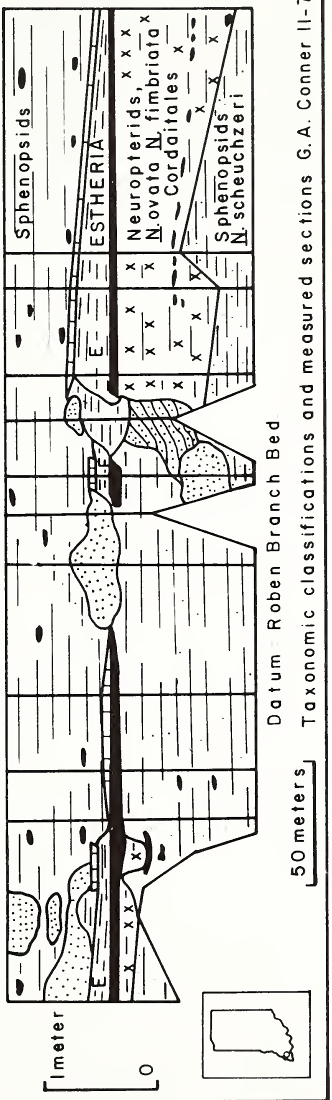


A northwest facing measured profile along Raben Branch (Figure 5) extends 450 meters southeast from Luigs Road. The stratal succession of floras is illustrated in the

STRATAL SUCCESSION OF FLORA IN A CONSTRUCTIONAL DELTAIC AND LACUSTRINE SEQUENCE OF RABEN BRANCH MEMBER WITH NEUROPTERIS OVATA - ST. WENDEL, INDIANA

TAXA REPRESENTED BY 835 SPECIMENS — **Figure 5**

SPHENOPSIDS (41)		TRUE FERNS (39)		N. plicata	16	N. obliqua	2
Annularia	2	Pecopteris	8	N. capitata	13	N. acuminatus	1
Asterophyllites	7	Asterotheca	3	N. clarksoni	8	N. agasizzi	2
Calamites	20	Ptychocarpus	28	N. rotundifolia	3	N. aspera	1
Calamariophyllum	1	SEED FERNS (664)		N. subfalcata	3	N. reniformis	1
Sphenophyllum	7	N. ovata	158	N. angustifolia	3	N. rarinervis	1
LYCOPODS (5)		N. loschii	156	N. hirsuta	3	N. scheuchzeri	2
Lepidophyllum	3	N. fimbriata	63	N. heterophylla	1	Cyclopteris	12
CORDIATALES (86)		N. flexuosa	55	N. gibbosa	1	C. trichomanoides	41
Cordaites	84	N. tenuifolia	37	N. callosa	2	Carpons	8
Cordianthus	2	N. vermicularis	37	N. collinsi	1	Pinnularia masses	40



Taxonomic classifications and measured sections G.A. Conner 11-74

constructional deltaic and lacustrine facies sequence described in ascending order. Light gray shales and sandy micaceous shales of the upper Dicksburg Hills Member contain predominantly Sphenospid stems, foliage fragments, and few spore bearing structures. Genera include *Calamites* cisti, *C.* suckowi, *Calamariophyllum*, *Calamostachys*, *Paleostachys*, *Sphenophyllum*, and *Asterophyllites*. True Ferns present are *Pecopteris* and *Ptychocarpus* unitus. The Seed Fern foliage population is generally limited to the larger pinnules of *Neuropteris* scheuchzeri and that group including *N.* hirsuta and *N.*

clarksoni. These sandy shale facies are interpreted as alluvial levee and channel margin deposits. The succeeding lithologic unit is a shale composed of bluish clay in contrast to the Dicksburg Hills sandy shales. This shale is weakly laminated with shows of fissility in the lower half. A ten centimeter zone of lenticular ferruginous nodules separates the lower half from the non-laminated upper half which resembles an underclay. The entire blue clay shale where present varies from a few centimeters to a maximum of two meters in thickness. This unit is interpreted as a lacustrine facies, possibly the middle or lower end of a lake delta. Flora extends through the entire thickness of the unit including the lenticular nodule zone. The list of genera and species in Figure 5 indicate a ubiquitous Seed Fern population of neuropterid fronds with *Ptychocarpus* unitus representing the True Ferns. *Cordaites* foliage is common and finely dismembered masses of *Pinnularia* are disseminated throughout the unit. Sphenopsids and Lycopods are absent in this shale. The Raben Branch Bed overlying this shale appears as a thin bright band or smut streak of coal generally six centimeters thick. Some partings reveal Sphenopsid stem compressions, neuropterid pinnules, and *Cordaites* segments. The *Estheria* zone lies above the coal. This zone includes a gray fissle shale 1 to 30 centimeters thick weathered in recess below a two centimeter orange band of ferruginous shale frequently jointed. The gray shale and ferruginous band contain abundant specimens of *Estheria*, a freshwater conchostrican. The valves are well preserved with a high lustre. *Calamites* cisti impressions occur on the lower surface of the ferruginous band.

Laminar and cross laminar constructional channel and levee facies laterally equivalent with the lacustrine neuropterid shale, Raben Branch bed, and *Estheria* zone contain abundant Sphenopsid stems and foliage fragments. This interval includes a silty gray shale and a lighter gray cross laminated micaceous sand. Laminations are generally three millimeters thick. Foliage fragments in the shale are sparse. *Calamites* cisti and *C.* suckowi in the sand occur in horizontal and vertical orientation without association to root structures. Overlying both sandy micaceous facies and the *Estheria* zone with a conformable contact is a gray clayey and silty shale bearing frequent flexure joints. Foliage in this unit is sparse, occurring in limonitic and hematitic nodules. Specimens of *Pecopteris*, *Ptychocarpus*, *Calamites*, *Calamariophyllum*, and *Lepidodendron* were found in proximity to yellow stained nodules containing pyritic valves of *Nucula* a brackish or freshwater pelecypod. These latter nodules were black in the interior resembling argillaceous carbonate bands associated with the Parker Limestone exposed farther upstream. This shale unit is variable in thickness in the area with truncation surfaces prior to deposition of the St. Wendel sandstone.

The five cubic meters of in-situ shale collected from Raben Branch contained 835 plant fragments excluding numerous pieces too small for practical identification. These were all taken from the two meter interval described, and contained taxa with identifications based upon the following classifications: L. Lesquereux's Coal Atlas, Adolph Brongniart's l'Histoire des Vegetaux Fossiles, and Gothan and Remy's Steinkohlenpflanzen. References to grouping together of different *Neuropteris* species based on similarities is in general agreement with W. Darrah's Critical Review of Pennsylvanian floras in the eastern United States. Representation of the five major plant groups found at Raben Branch (Figure 5), includes 41 Sphenopsides, 5 Lycopods, 86 Cordaitales, 39 True Ferns, and 664 Seed Ferns including 8 Carpons.

Variation of pinnule form and vennation in Neuropteris ovata and related species at Raben Branch

Pinnule dimorphism within a second order frond rachis, and more than 18 species of the arborescent Seed Fern *Neuropteris* is observed in specimens from the blue shale below the Raben Branch Bed.

Neuropteris ovata Hoffman, *N.* loschii Brongniart, and *Neuropteris* fimbriata are the dominant specis. *N.* fimbriata occurs in a variety of pinnule forms in basal, lateral, and terminal positions on the rachis. *Cylcopteris* trichomanoides is common as a basal pinnule with fimbriate margins. Several fronds illustrate a variety of pinnatification stages of pinna along a secondary rachis. *N.* vermicularis pinnules are opposite *N.* flexuosa. *Neuropteris* subfalcata shows variations in pinnule morphology of the basal auricle. Several specimens of mixoneurid vennation and uncommon variations of terminal pinnules and cardioid basal pinnules appear on a rachis of *N.* ovata. These suggest a transition modification precursory to the final stages of Westphalian E or early Stephanian neuropterids of the Cantabrien and Saar-Lorraine Basins of Europe.

Facies association and depositional sequences

All of these specimens together in the assemblage of the blue lacustrine shale indicate an abrupt change from the underlying Dicksburg Hills Member with detached large pinnules of *N.* scheuchzeri and *N.* hirsuta in a predominately Sphenopsid stem population. Numerous exposures of the Dicksburg Hills Member and underlying Inglefield Member on the Kasson and West Franklin Quadrangles examined in detail reveal occurrences of *N.* scheuchzeri pinnules with numerous *Calamites* and *Lepidodendron* casts and compressions. The reason for this abrupt occurrence of neuropterids in the Raben Branch coal flora must be related to preservation in a somewhat unique lithology and depositional environment of rapid preservation and lower energies than persisted in the sandy facies below. Perhaps in a more upland area than was common for the preceding coal floras in the region. Recalling D.D. Owen's and Charles Lyell's observation of Lycopod forest floors in the shales of Big Creek several kilometers west and downdip from Raben Branch, these beds are probably from the cyclothemic sequence which followed the St. Wendel sandstone in the area. Foliage inventories were not described probably because foliage was weathered before burial of the growth floor. The closest evidence for a Medullosan growth floor for the neuropterids at Raben Branch lies perhaps two to three meters below the Parker Coal where *Psaronious* rootlets occur in coal-ball petrifications, but this indication is of a later floor than that associated with the blue shale. Consequently it is agreeable to infer that the medullosan growth floor above the blue lacustrine shale was destroyed or lies some distance away in the facies sequence not exposed. Remarkably, what may be the most prolific deposit of neuropterids in Indiana occurs 100 meters above the unnamed shale Member of the Shelburn Formation of Indiana investigated by R. Pheifer (1979) whose thesis included identification of more than 12,000 specimens of coal flora including only several species of neuropterids. There is a different lithological character as well as depositional sequences and thicknesses in the cyclothems of Illinois Basin below and above the base of the Conemaugh. Coal flora descriptions of these younger units are few however the frequency of neuropterids in the coal and clay below the Cuttoff sandstone below New Harmony suggests another deposit similar to Raben Branch with a similar depositional sequence. During 1974 approximately 50 specimens of *Neuropteris* ovata, *N.* hirsuta, *N.* scheuchzeri, and *N.* fimbriata were collected from below the coal at the Cuttoff. *N.* ovata showed a slightly more robust lateral pinnule form than those at Raben Branch 12 miles due east. The position of this coal above the Raben Branch Bed is by estimation 80 meters; and is 180 meters above the base of the Conemaugh Series in Indiana. The relation to the Raben Branch Bed was determined using the West Franklin and Parker limestones as reference on electrical resistivity logs and noting displacement along the New Harmony Fault. The relation of the Cuttoff sandstone described by D.D. Owen (Owen, D.D. 1859, p. 6) to the upper Conemaugh units exposed in Indiana, Illinois, and Western Kentucky has not been demonstrated with certain precision for several reasons. Further stratigraphic investigations of these upper Conemaugh strata and comparison of the Raben Branch coal flora to the upper Westphalian and lower Stephanian throughout the Euramerican province are in progress. All specimens from Raben Branch to be published in descriptions are housed in the Indiana University Paleobotany Collections in Bloomington, Indiana.

Literature Cited

1. Artis, E.T. 1838. Antediluvian Phytology: Nichols and Sons, Parliament Street, London.
2. Brongniart, A. 1828. Histoire des vegetaux fossiles: G. Dufour et E. D'Ocagne, Paris. Texte et Atlas.
3. Cox, E.T. 1876. Geological survey of Indiana; 7 th. annual report, made during 1875: 601 p., 2 pls., 1 fig., 4 maps.
4. Collett, J. 1884. Indiana Dept. of Geology and Natural History: 13 th. annual report. Geology of Posey County p. 45-70.
5. Darrah, W.C. 1969. A critical review of the upper Pennsylvanian floras of the eastern United States with notes on the Mazon Creek flora of Illinois: Monograph. Gettysburg College.
6. Fidlar, M.M. 1933. Some hills of circumalluviation in the lower Wabash Valley: Proc. Ind. Acad. Sci., v. 42. 1932 (1933). P. 135-140.
7. Fuller, M.L. and Clapp, F.C. 1904. Description of the Patoka Quadrangle: U.S. Geol. Survey Geol. Atlas Folio 105, 12 p., 13 figs., 2 maps.
8. Gothan, W. and Remy, W. 1957. Steinkohlenpflanzen: Verlag Gluckauf GMBH Essen.
9. Hall, J.W. 1952. The phloem of *Heterangium* americanum: Am. Midland Naturalist, v. 47, no. 3. p. 763-768.
10. Jongmans, W.J. 1937. Some remarks on Neuropteris ovata in the American Carboniferous: in Compte Rendu, Deuxieme Congress pour l'avancement des etudes de stratigraphie Carbonifere (Heerlen 1935) Tome 1. Gebrs. Van Aelst. Maestricht.
11. Lesquereux, L. 1859. Report on the distribution of the geological strata in the Coal Measures of Indiana: in Continuation of a geological reconnaissance of the State of Indiana made in the year 1838, in conformity to an order of the legislature. By D.D. Owen, M.D. State Geologist. Second Part.
12. Lesquereux, L. 1866. Report on the fossil plants of Illinois: Section III in Geological survey of Illinois, v. 2., Paleontology. A.H. Worthern, Director. Western Engraving Co., Chicago.
13. Lesquereux, L. 1878-1880. Description of the coal flora of Pennsylvania and of the Carboniferous formation throughout the United States. Vol. 1 and 2. Atlas: Second geological survey of Pennsylvania: Report of Progress. Harrisburg.
14. Lindley, J. and Hutton, W. 1831-1837. The fossil flora of Great Britain: James Ridgeway and Sons, Picadilly.
15. Lyell, C. 1849. A second visit to the United States of North America: Vol. 2: John Murray, Abermarle Street. London.
16. Malott, C.A. 1922. The physiography of Indiana, in Logan, W.N., and others, Handbook of Indiana Geology: Indiana Dept. of Conserv. Pub. 21, pt. 2, p. 59-256, 3 pls., 51 figs.
17. Malott, C.A. 1933. Structure map of the St. Wendells area Vanderburg and Posey Counties, Indiana. (and) Detail stratigraphy of the Parker formation and the Estheria zone below: Unpublished map and column.
18. Malott, 1939. The Hazelton Bridge Formation of the upper Pennsylvanian of southwestern Indiana (abs.): Indiana Acad. Sci. Proc. for 1938, v. 48, p. 114.
19. Malott, C.A. 1948. The geology of the Dicksburg Hills, Knox County, Indiana: Indiana Acad. Sci. Proc. for 1947, v. 57, p. 125-141, 1 fig.

20. Owen, D.D. 1943. On some fossil palm trees from new Harmony, Indiana: Acad. Nat. Sci. Philadelphia Proc., v. 1. p. 270-271.

21. Owen, D.D. 1856. Report of a geological survey in Kentucky, made in 1854-1855: Frankfort, Ky. Kentucky Geol. Survey v. 1. 416 p.

22. Owen, D.D. 1859. Report of a geological reconnoissance of the State of Indiana made in the year 1837: Indianapolis, pt. 1, 63 p.

23. Owen, R.D. 1862. Report of a geological reconnoissance of Indiana, made during the years 1859 and 1860, under the direction of the late David Dale Owen, M.D., State Geologist: Indianapolis, H.H. Dodd and Co. 368 p., 8 pls.

24. Pheifer, R.N. 1979. The paleobotany and paleoecology of the unnamed shale overlying the Danville Coal Member (VII) in Sullivan Co., Indiana: Ph.D. Dissertation, Indiana University, Bloomington.

25. Schlotheim, F.B. 1804. Beitrag zur FLora der Vorwelt Beschreibung merkwurdiger Krauter-Abdrucke und Pflanzen-Versteinerungen. Gotha.

26. Schrock, R.R. and Malott, C.A. 1929. Structural features of the West Franklin Formation of Southwestern Indiana, Amer. Assoc. Petr. Geol., vol. 13, 1301-1314.

27. Wilson, W.E. 1964. The Angel and the Serpent: Indiana University Press: Bloomington. 242 p.

28. Witham, H.T. 1833. The internal structure of fossil vegetables found in the carboniferous and oolitic deposits of Great Britain described and illustrated: Edinburgh, A.A. Black, 84 p. plates.

Stream-variable Response to a Change in Surficial Geology: Middle Fork, Big Walnut Creek, Hendricks County, Indiana

Paul K. Doss
David E. Grow
Robert D. Hall
Department of Geology
Indiana University-Purdue University
Indianapolis, Indiana 46202

Introduction

The Middle Fork of Big Walnut Creek flows across a contact between Wisconsinan glaciolacustrine sediments (upstream) and outwash (downstream) in northwestern Hendricks County, Indiana (Figure 1). Preliminary field observations suggested that cor-

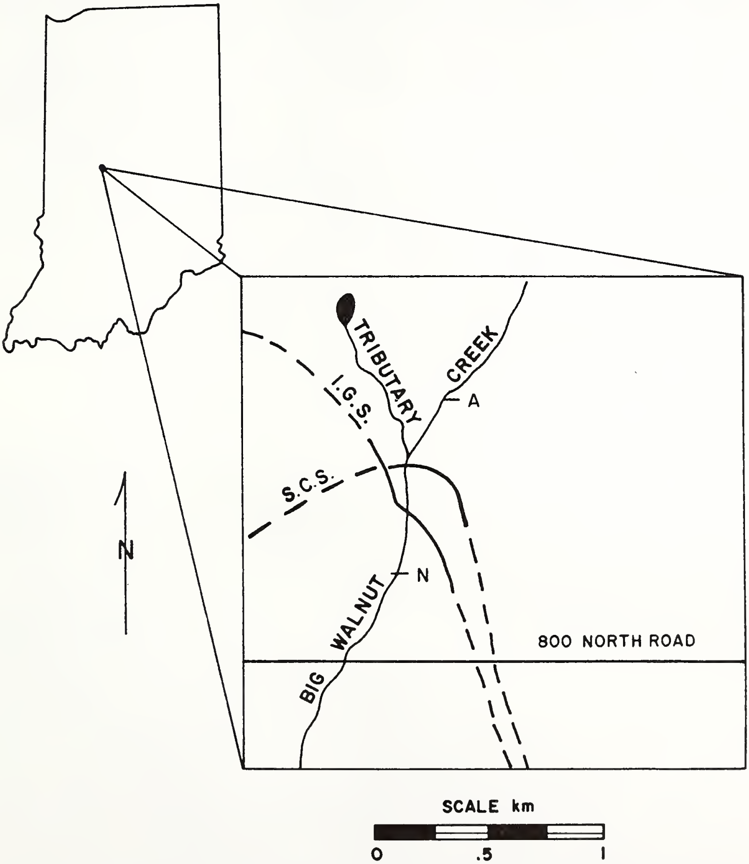


Figure 1. Location of study area. The study reach of Middle Fork, Big Walnut Creek is between stations A and N. S.C.S. and I.G.S. indicate positions of the contact between Wisconsinan glaciolacustrine sediments (upstream) and outwash (downstream) as mapped by the Soil Conservation Service (6) and the Indiana Geological Survey (1), respectively.

responding changes occur in the geometry of the channel cross sections in this area (Figure 2).

The purposes of this study are to determine: (1) if this reach of Big Walnut Creek is in equilibrium with its geologic setting, and (2) how sediment and stream-channel characteristics reflect a difference in the geology of the surficial materials along the study reach of the stream.

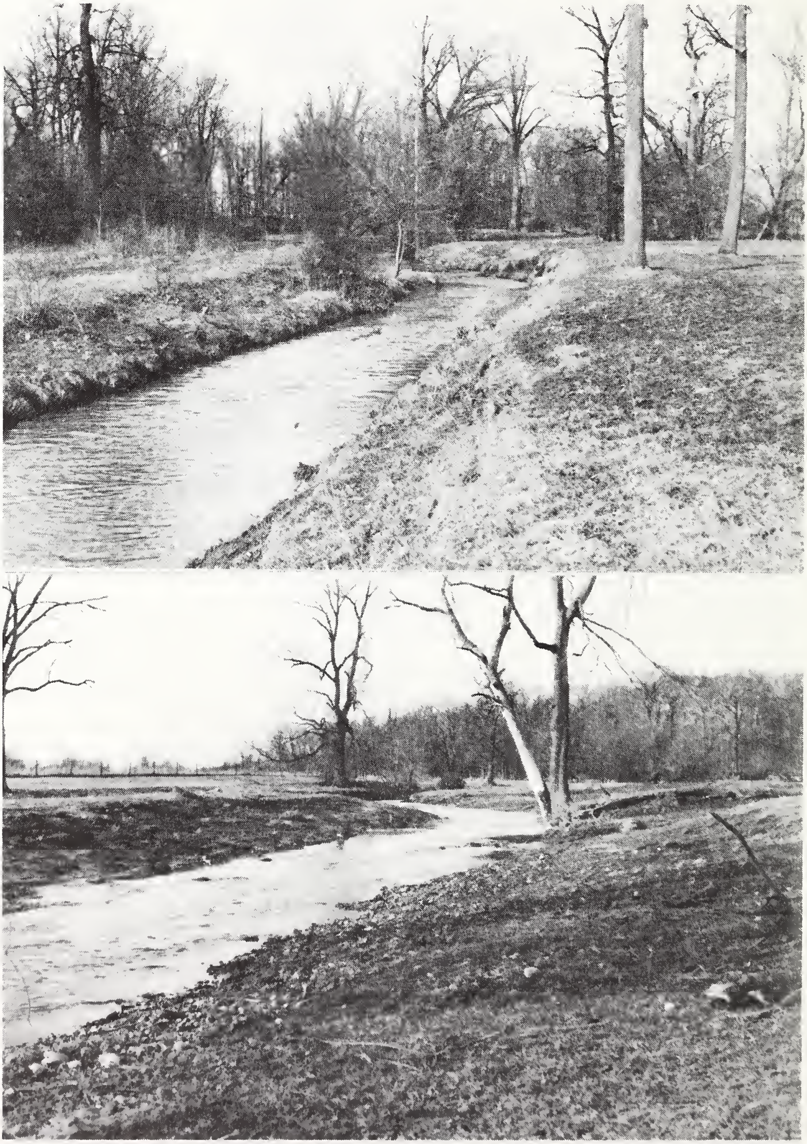


FIGURE 2. General channel form in upstream (A) and downstream (B) parts of study reach.

Fourteen stations were established in March 1985, during moderate streamflow, along a study reach of 791 meters (Figure 3). The stations were established at pools midway between riffles. At each station, water-surface elevation and cross-section geometry were determined, and suspended sediment and bed material were sampled.

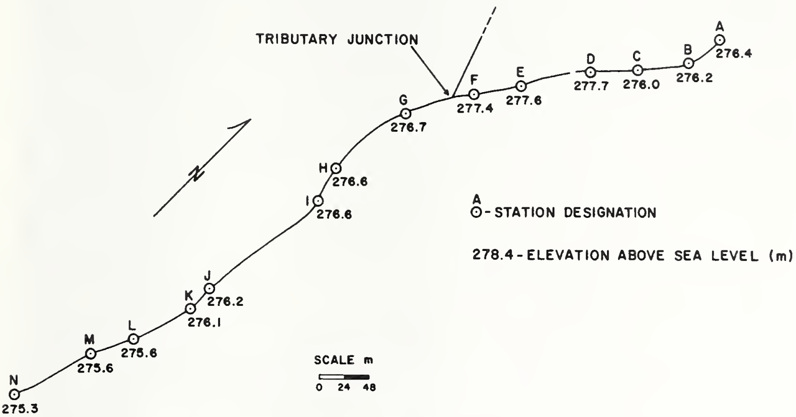


Figure 3. Map of the study reach showing locations and elevations of stream surface at stations. Also shown is the location of the tributary junction.

Geology of Surficial Materials

Hendricks County, Indiana, is located in the Tipton Till Plain of central Indiana (10). The thickness of Wisconsinan surficial materials ranges from zero to greater than 61m. These materials include till, outwash, and glaciolacustrine sediments. Holocene alluvium occurs along streams (1).

The study reach was chosen with its midpoint at the contact between the glaciolacustrine sediments and outwash. The glaciolacustrine sediments upstream from this contact are mostly poorly-laminated sandy silts and clays (Figure 4), although th overall grain size ranges from clay to coarse sand with widely scattered small pebbles The soils formed in the glaciolacustrine sediments are poorly-drained sandy loams o the Rensselaer-Whitaker association (6).

The outwash downstream from the contact is moderately to poorly sorted and stratified (Figure 5). The grain size ranges from clay to cobbles. The soils formed in th outwash are well-drained gravelly clay loams of the Ockley-Martinsville-Fox associatio (6).

External Variables

Aerial photographs taken from 1946 to 1978 reveal that channelization occurre along parts of Big Walnut Creek, including the study reach, prior to 1946. Channelization resulted in a straight channel pattern, which has been maintained over the last 4 years. However, no other effects of channelization upon the stream were noted.

Within the study reach, Big Walnut Creek is joined by a small tributary (Figure 1 and 3). This tributary flows approximately 600 meters from a small pond which ac to moderate flow and trap sediment. The tributary channel is small compared to th of the main stream. It had negligible flow during the period of the study and showe no evidence of previous high flow.

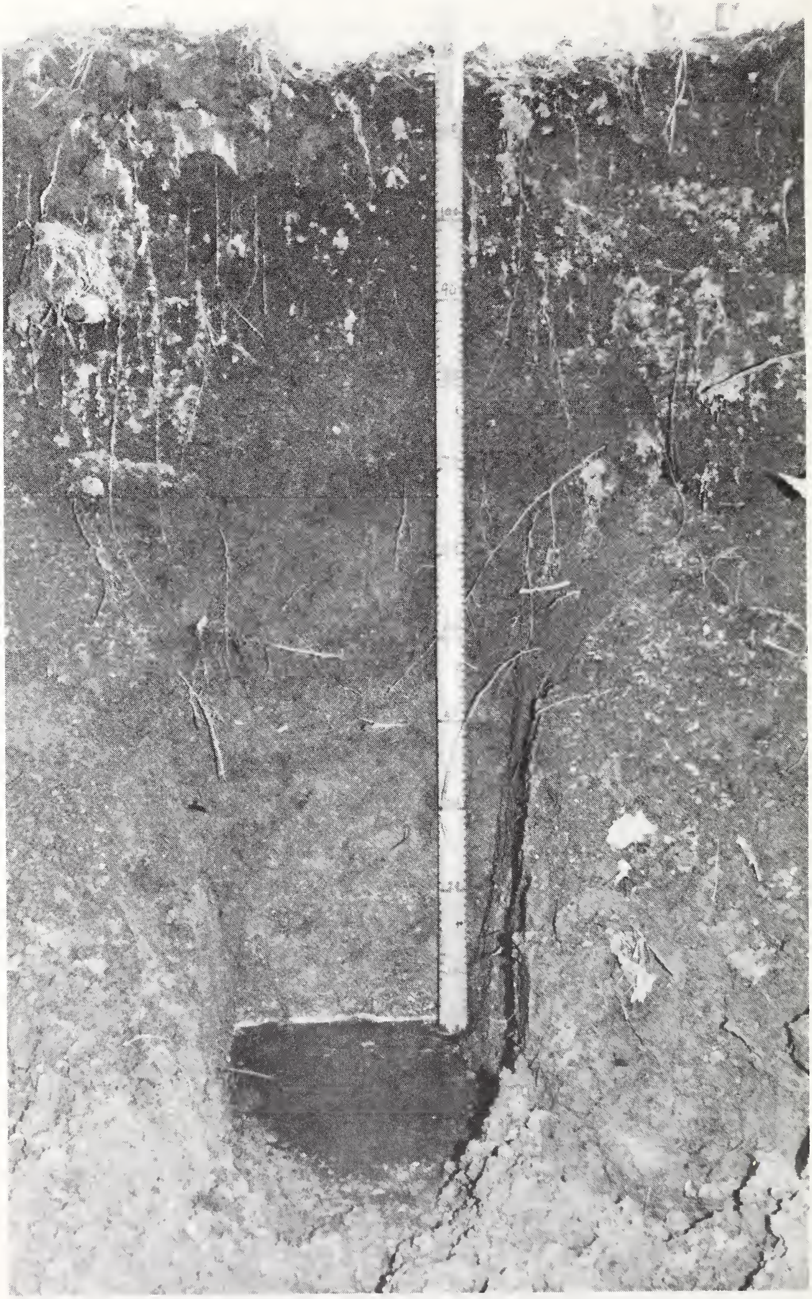


FIGURE 4. Glaciolacustrine sediments along upstream part of study reach. The exposure is 1.2 meters thick.

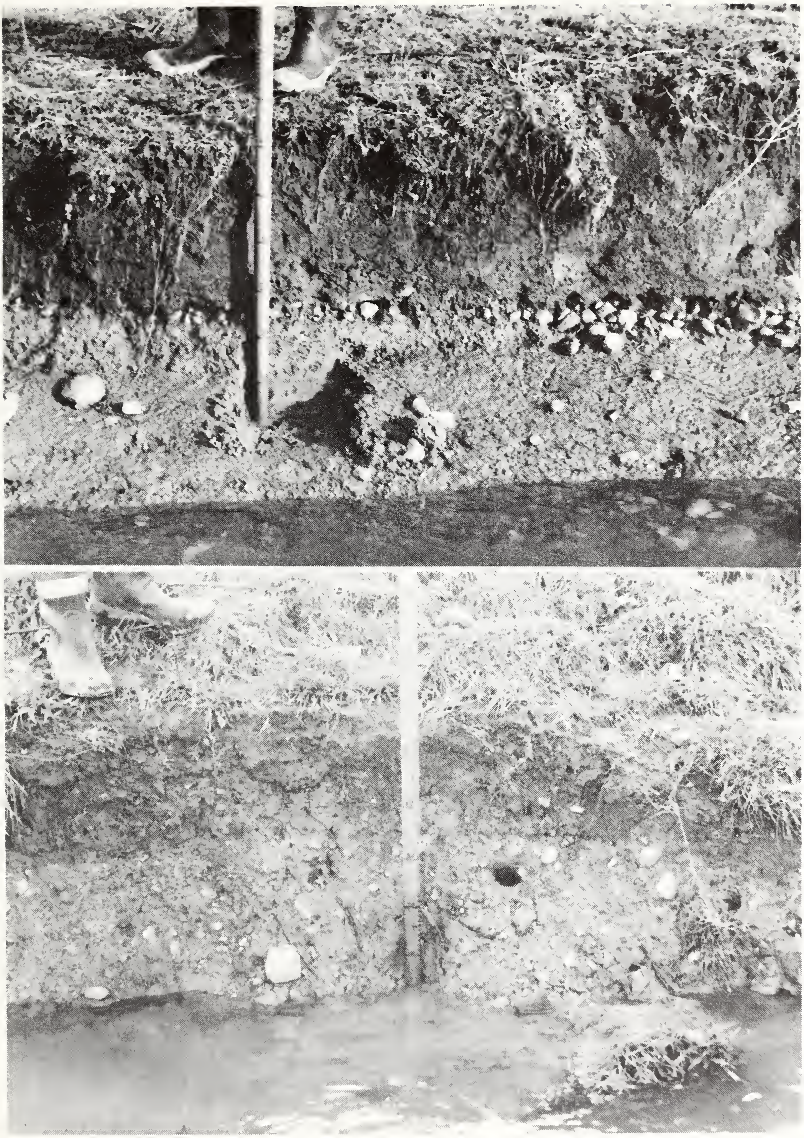


Figure 5. Outwash along downstream part of study reach. The exposures are 0.6 meters thick.

Agricultural drain tiles add some discharge along the study reach. However, at the time of the study, no discharge from the tiles was observed, and the effects along the study reach were assumed to be minimal.

Channel-bank modification occurs at livestock-watering sites, but the effects are localized, and such sites were avoided during collection of data.

Methodology

Stations were mapped, and elevations were determined with plane table and alidade. Elevations were established at the water surface and used to determine stream slope.

Bed-material samples were obtained at the thalweg of each station by taking the uppermost 3 to 6 centimeters of bed material with a manual cannister sampler. Samples were analyzed for grain size using the dry-sieving method (2). All grain-size determinations are based on the modified Wentworth scale (4).

A US DH-48 depth-integrating wading-type sampler was used to collect samples of suspended sediment. One sample was taken at the thalweg of each station (3). The concentration of suspended sediment was determined using the evaporation method (2).

The geometry of the cross section at each station was determined by establishing a level line across the stream and measuring depth across the channel at 20-centimeter intervals.

Results and Discussion

The following discussion of the variables measured or determined along the study reach will be made with reference to stations A through N (Figure 3, Table 1). Trends and clusters in the data will be related to distance downstream within the reach. The discussion of suspended sediment, bed material, stream slope, and channel shape will focus upon a consideration of the hydraulic geometry of the study reach.

Table 1. Data collected at stations along the study reach of Big Walnut Creek.

							Bed Material		
Station	Elevation (m)	Distance Downstrm. (m)	Channel Width (m)	Channel Depth (m)	W/D	Mean Gr. Sz. (ϕ)	Vol. % Gravel	Wt. % Silt + Clay	Susp. Sed. Conc. (mg/l)
A	278.4	0	5.92	0.52	11.6	1.68	1	1.20	23.2
B	278.2	39.6	4.24	0.57	7.4	0.82	4	0.61	25.8
C	278.0	88.4	5.80	0.64	9.1	1.28	2	0.20	21.0
D	277.7	134.1	5.28	0.62	8.5	0.09	39	0.25	13.3
E	277.6	201.2	4.88	0.45	11.9	1.34	7	0.15	20.8
F	277.4	246.9	6.24	0.71	8.4	0.07	28	0.05	37.3
G	276.7	315.5	4.80	0.51	9.5	N/A	43	N/A	31.8
H	276.6	403.9	5.20	0.33	15.6	1.05	25	0.23	31.6
I	276.6	440.5	6.84	0.25	27.2	0.50	33	0.08	31.6
J	276.2	576.6	5.80	0.31	18.7	−0.25	60	0.13	23.3
K	276.1	602.0	6.00	0.35	17.1	−0.55	67	0.08	28.0
L	275.8	663.0	6.32	0.28	22.6	−0.66	75	0.04	35.8
M	275.6	708.7	5.64	0.37	15.2	−0.36	60	0.08	34.2
N	275.3	791.0	5.52	0.45	12.8	1.41	13	0.89	26.0

Suspended Sediment

The concentration of suspended sediment shows no significant changes or trends downstream through the study reach. Furthermore, the tributary does not introduce significant amounts of suspended sediment (Table 1).

Bed Material

From the samples of bed material, analyses were made for the weight percent of silt + clay, mean grain size, and volume percent of gravel. No significant trends or groupings were apparent in the weight percent of silt + clay along the study reach.

The plot of mean grain size versus distance downstream shows two groupings or clusters in the data (Figure 6). Stations A through F have an average mean grain size of about 0.9ϕ, whereas stations H through N have an average mean grain size of about 0.2ϕ. A Student t-test indicates a significant difference in mean grain size between the two groups at a confidence level of 0.10.

Two groupings are also apparent in the plot of volume percent gravel versus distance downstream (Figure 7). Stations A through G have an average of about 18 volume percent gravel, whereas stations H through N have an average of about 48 volume percent. A Student t-test indicates a significant difference in abundance of gravel between the two groups at a confidence level of 0.025.

Stream Slope

The slope of the water surface along the entire study reach is 0.0039 (Figure 8). The slope is interrupted and deviates from this value between stations F and H. This "bench" in the slope is probably a consequence of the tributary junction between stations F and G (Figure 3). Because the tributary does not contribute a significant amount of suspended sediment to the main stream (Figure 3, Table 1), the additional discharge supplied by the tributary apparently results in scouring of the channel between stations F and G. Below that point, the stream's sediment load is increased, and the channel is aggraded between stations G and H. Below station H the stream resumes its original channel slope (Figure 8). Excluding the "bench" from the profile would result in an essentially constant slope.

However, such a constant slope might not be expected when considering the change in bed material along the stream. Although Schumm (9) suggests that the introduction of coarse bedload material should result in a steepening of the stream slope, such steepening does not occur along the reach in our study area where the stream encounters the gravel-rich outwash.

Channel Shape

According to Ritter (5), the introduction of a different type of load may result in a change in channel shape instead of a change in gradient. Such a change is apparent in our study reach. Cross sections at stations G and J have been selected as typical of the upstream and downstream parts of the study reach, respectively (Figure 9). The difference is quite apparent.

A plot of channel width versus distance downstream (Figure 10) shows very little change (regression slope = 0.0009) along the study reach. However, a plot of channel depth versus distance downstream (Figure 11), shows the data in two groupings, stations A through G and stations H through N. A Student t-test indicates a significant difference in channel depth between the two groups at a confidence level of 0.01. A plot of the width/depth ratio versus distance downstream (Figure 12) again shows two groupings. Channel shape is believed to be independent of discharge (8) but dependent on sediment type (5).

The channel shape in the study reach is apparently controlled by the geology of the surficial materials. If the materials in which the channel is cut are highly cohesive, as in the glaciolacustrine sediments of the upstream part of the study reach, the channel will be deep. If the bank materials lack cohesion, as in the outwash of the downstream part of the study reach, the channel will be shallow (8).

Hydraulic Geometry and Dynamic Equilibrium

A constant slope throughout the study reach, even with the change in surficial materials, suggests that the stream is in equilibrium with its geologic framework. The

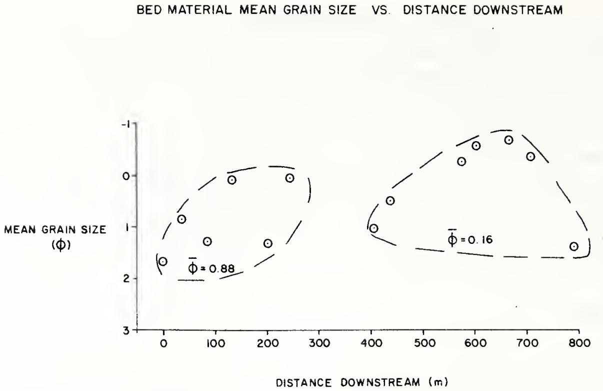


FIGURE 6. Mean grain size of the bed material versus distance downstream.

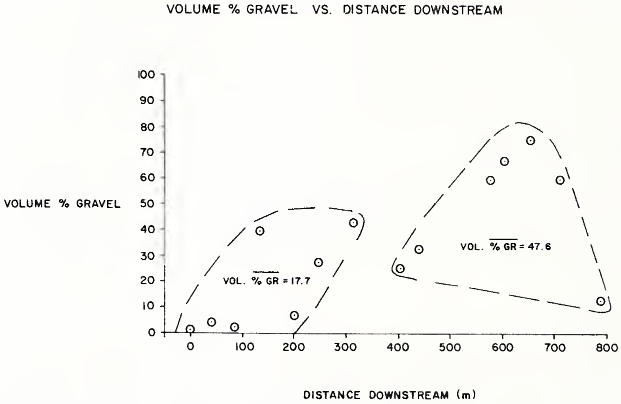


FIGURE 7. Volume percent gravel in the bed material versus distance downstream.

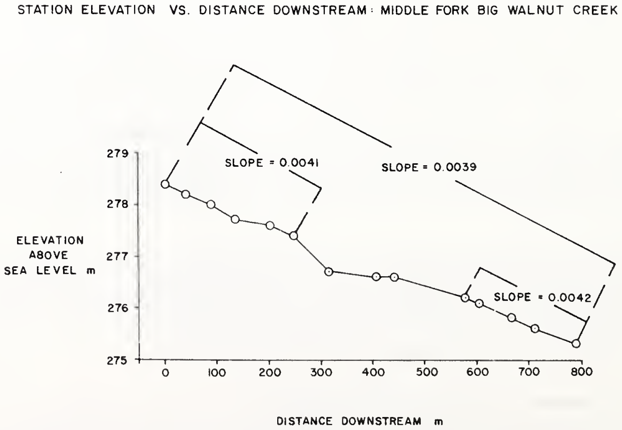


FIGURE 8. Longitudinal profile of the study reach of Big Walnut Creek.

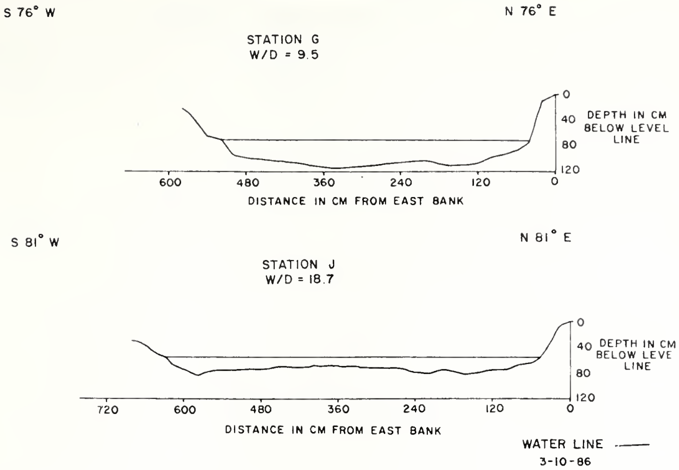


FIGURE 9. Representative channel cross sections for upstream (Station G) and downstream (Station J) parts of study reach.

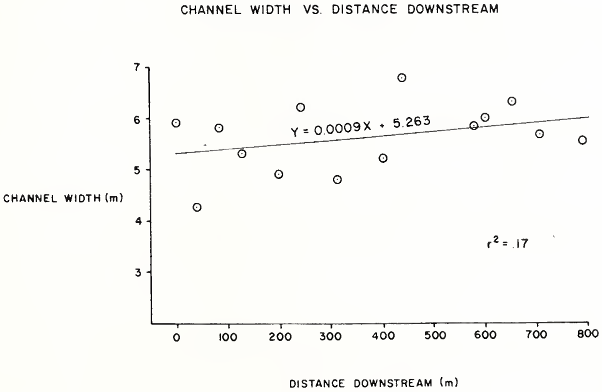


FIGURE 10. Channel width versus distance downstream.

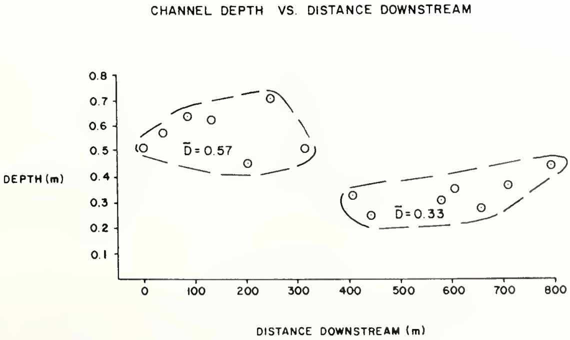


FIGURE 11. Channel depth versus distance downstream.

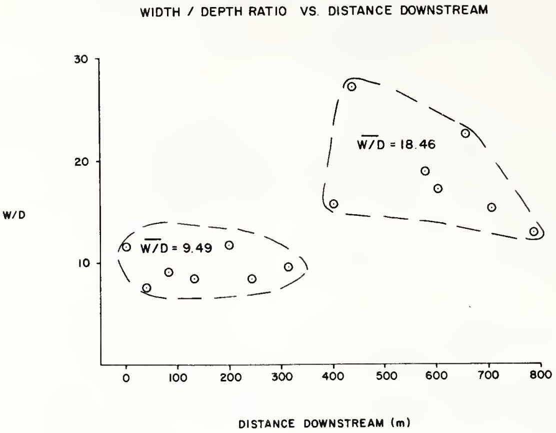


FIGURE 12. Width/depth ratio versus distance downstream.

data indicate that other hydraulic variables are actively responding to the change in bed material in order to maintain that equilibrium.

Our approach to understanding how this response is occurring is based on the flow equation

$$Q = AV$$

where Q = discharge, A = cross sectional area, and V = velocity. With constant discharge along the study reach

$$Q_1 = Q_2 \text{ or } W_1D_1V_1 = W_2D_2V_2$$

where 1 and 2 designate the upstream and dosnstream parts of the study reach.

The Manning equation was used to obtain estimates of average velocity for channel cross sections in the two parts of the study reach. The Manning equation is

$$V = 1.49/n\ R^{2/3}S^{1/2}$$

where V = velocity, n = Manning roughness coefficient, R = hydraulic radius, and S = stream slope. Roughness coefficients were estimated from published tables (7). Using $n_1 = 0.030$ and $n_2 = 0.035$, estimated average velocities are $V_1 = 1.30$ m/sec and $V_2 = 1.96$ m/sec. The velocity increases by about 50 percent from the upstream part to the downstream part of the study reach.

This analysis indicates that velocity and depth are the actively-adjusting hydraulic variables, permitting the stream to sustain an equilibrium with its geologic framework. Where gravel-rich sediment from the outwash is introduced, an increase in velocity is needed to transport the sediment load. Because the channel width remains almost constant, a decrease in depth is needed to satisfy the flow equation. Not only does the stream show a 50 percent increase in velocity in the part of the study reach through the outwash, but a decrease in depth effectively increases the ratio of velocity acting on the channel bottom to velocity acting on the channel sides (8). This results in an increased capability to transport bedload, and a simultaneous decrease in the cross-sectional area.

Conclusions

The responses of particular stream variables to internal and external factors are well observed along the study reach of Big Walnut Creek. An increase in grain size of the surficial materials surrounding the stream occurs between stations G and H. This change in surficial materials results in distinct changes in channel shape and velocity in order to provide the energy necessary to transport the coarser load, and at the same time permit the stream to maintain a constant slope of the water surface. The response of specific internal variables to changing lithologic controls maintains the dynamic equilibrium of the system.

Acknowledgments

We wish to thank Brent Graves for his assistance in the field and the staff of the Hendricks County Office of the United States Soil Conservation Service for their cooperation.

Literature Cited

1. Gray, H.H., N.K. Bleuer, J.R. Hill, and J.A. Lineback. 1979. Geoogic map of the 1° × 2° Indianapolis Quadrangle, Indiana and Illinois. Indiana Geological Survey. Regional Geologic Map No. 1.
2. Guy, H.P. 1969. Laboratory theory and methods for sediment analysis. United States Geol. Surv. Techniques of Water Resources Invetig., Book 5, Ch. C1, 58 p.
3. Guy, H.P. and V.W. Norman. 1970. Field methods for measurement of fluvial sediment. United States Geol. Surv. Techniques of Water Resources Invetig., Book 3, Ch. C2, 59 p.
4. Ingram, R.L. 1982. Grain size scale used by American geologists. *In* R.V. Dietrich, J.T. Dutro, Jr., and R.M. Foose, AGI Data Sheets.
5. Ritter, D.F. 1986. Process Geomorphology. Wm. C. Brown Publ. Co., Dubuque, Iowa. 579 p.
6. Robbins, J.M. 1974. Soil survey of Hendricks County, Indiana. United States Soil Conservation Service. 133 p.
7. Ruhe, R.V. 1975. Geomorphology. Houghton Mifflin Publ. Co., Boston, Mass. 246 p.
8. Schumm, S.A. 1960. The shape of alluvial channels in relation to sediment type. United States Geol. Surv. Prof. Paper 352-B:17-30.
9. Schumm, S.A. 1968. River adjustment to altered hydrologic regimen. Murrumbidgee River and paleo-channels, Australia. United States Geol. Surv. Prof. Paper 598. 65 p.
10. Wayne, W.J. 1956. Thickness of drift and bedrock physiography of Indiana north of the Wisconsin glacial boundary. Indiana Geol. Survey Report of Progr. 7. 70 p.

Spotting Spurious Stream Names on Topographic Maps of Indiana[1]

Henry H. Gray
Indiana Geological Survey
Bloomington, Indiana 47405

Introduction

The 1:24,000-scale topographic maps prepared by the U.S. Geological Survey constitute a vast reservoir of data of great interest to students of geographic names. For most states, the Geological Survey has also made available an alphabetical finding list of these names. There are nearly 19,000 names on the Indiana list; unfortunately, many of the stream names listed are spurious.

About 1960, during the heyday of topographic mapping in Indiana, in a misguided attempt to name all drainage features that appear on these maps, many fictitious stream names were arbitrarily applied during review of the maps by a former state agency. Many of these names are frivolous or fanciful; most of these can readily be detected. Others may be reasonably derived but have no local legitimacy. A few might be demonstrated to be in error through study of historic maps, reports, and legal documents.

When the Indiana Board on Geographic Names was organized, early in 1961, it requested an end to the practice of generating stream names, but much damage had already been done. Hundreds of topographic maps had been prepared, revised, reviewed, and printed during the period when the spurious names were being applied, and thousands of these non-valid names now are before the public.

Detection and avoidance of these names by those who are interested in the validity of geographic names range from ludicrously easy to rather difficult. Because of the expense and time required to research the names and to expose the phonies, many of these names probably will remain on Indiana maps for some time to come. Some may ultimately come to be accepted. It is the purpose of this paper to bring examples of these spurious names to view, to warn against their unwary acceptance, and to illustrate some of the ways in which the non-valid names can be detected.

Examples: the Shoals Quadrangle

Table 1 lists drainage names for the Shoals Quadrangle, Martin County, in a sort of geographic order, comparing names on the 1960 edition with names on the 1950 edition. The later edition had, quite obviously, the very questionable benefit of the addition of many names — a total of 57 names as compared with 12 on the earlier map. This very high name density — something approaching one name per square mile of map — is the first clue that the names pattern has been tampered with.

The name Willow Creek is apparently legitimate because it appears on the older map, the map that was made when U.S. Geological Survey topographers actually spent major time in the field and made a serious effort to determine names of local usage. Poplar Creek and Elm Creek nearby are questionable only on the basis of their absence from the earlier map, but assuming that Elm Creek is a legitimate name, then American Run appears to have been inspired by that (i.e., American elm) and French Run and Indian Run (in possible reference to the French and Indian war) by American. Plaster Creek perhaps suggested Lime, which then suggested Lemon. Spout Spring, a legitimate name, apparently generated Spurt, Jet, Squirt, and perhaps Gushing. Most of these names I would classify as fanciful, and I am sure all are fictitious.

Mt. Union Church evidently evolves into Mountain Stream, Union Creek, and Church Brook. Any one of these might be legitimate, but in combination they disclose their spurious origin. Furthermore, the generic terms stream and brook are rare in Midwest

TABLE 1. Names of drainage features shown on the U.S. Geological Survey Shoals Quadrangle topographic map, scale 1:24,000, 1960 and 1950 editions. Names in parentheses are those of cultural and other features from which some of the drainage feature names may have been derived. Asterisks indicate names not present on 1960 edition.

1960	1950
Poplar Creek	
(Poplar Grove Church)	(Poplar Grove Church)
Houghton Run	
Willow Creek	Willow Creek
Windy Run	
Grove Brook	
*	(Beech Grove School)
Elm Creek	
American Run	
Indian Run	
French Run	
Plaster Creek	Plaster Creek
Lime Run	
Lemon Run	
Lacy Drain	
(Lacy)	(Lacy)
Virginia Rill	
East Fork White River	East Fork White River
Nubbin Ridge Branch	Nubbin Ridge Branch
Spurt Run	
Jet Run	
Squirt Run	
Spout Spring	Spout Spring
Gushing Creek	
Sherfick Stream	
*	(Sherfick School)
Beaver Creek	Beaver Creek
Beaver Creek (applied in error to a small tributary)	
Iron Creek	
(Ironton)	(Ironton)
Speel Creek	
House Rock Branch	House Rock Branch
(House Rock)	(House Rock)
Freemans Spring Branch	Freemans Spring Branch
Free Run	
Boggs Creek	Boggs Creek
Buzzard Run	Buzzard Run
Nest Brook	
Mountain Stream	
Union Creek	
Church Brook	
(Mt. Union Church)	(Mt. Union Church)
Knob Branch	
Buck Knob Creek	
(Buck Knob)	(Buck Knob)
Sod Run	
Seed Tick Creek	Seed Tick Creek
River Drain	
Beech Creek	Beech Creek
Nut Brook	
Limb Run	
Branch Run	
Root Brook	
Leaf Branch	
Peek Run	
(Peek Cut)	(Peek Cut)

TABLE 1.—Continued

1960	1950
Overlook Drain	
(Shoals Overlook)	(Shoals Overlook)
Hickory Run	
Cedar Brook	
(Cedar Bluff)	(Cedar Bluff)
Flood Run	
Indian Creek	Indian Creek
Opossum Creek	
Poss Creek	
Sum Creek	
Opo Run	
Hill Branch	
Dover Run	
(Dover Hill)	(Dover Hill)
57 named streams	12 named streams

usage. Beech Creek leads to Nut, Limb, Branch, Root, and that triumph of *double entendre*, Leaf Branch. Opossum Creek, probably 'Possum to the natives if it is valid at all, and it may be, is dissected into Poss, Sum, and Opo. These are not just spurious names, they are facetious.

More examples: the New Albany Quadrangle

On the 1965 edition of the New Albany Quadrangle, Floyd and Clark Counties (Table 2), there are Bow Run, Arrow Run, and War Run, all tributary to Little Indian Creek. In the same area are St. Marys Run, Church Run, and Cross Branch, all derived presumably from St. Marys Church. Perhaps the lamb of Lamb Run was in the churchyard. Falling Run has a confusing and probably spuriously named tributary, Fall Run, and the defunct Valley View Golf Course, most of which now lies beneath Interstate

TABLE 2. Names of drainage features shown on the U.S. Geological Survey New Albany Quadrangle topographic map, scale 1:24,000, 1965 and 1955 editions. Names in parentheses are those of cultural and other features from wich some of the drainage feature names may have been derived. Asterisks indicate names not present on 1965 edition.

1965	1955
Clear Fork	Cleark Fork
French Creek	French Creek
Pine Run	
(Pine Hill)	(Pine Hill)
Middle Creek	Middle Creek
Vincennes Run	
(Old Vincennes Road)	(Vincennes Road)
Corydon Run	
(Corydon Pike School)	(Corydon Pike, School)
Little Indian Creek	Little Indian Creek
Floyds Creek	
(Floyds Knobs)	(Floyds Knobs)

TABLE 2.—Continued

1965	1955
Crooked Run	
Bow Run	
Arrow Run	
War Run	
Atkins Run	
(Atkins Road)	
Lamb Run	
Cross Branch	
Church Run	
St. Marys Run	
(St. Marys)	(St. Marys Church)
Silvercrest Run	
(Silvercrest State Hospital)	(Silvercrest State Hospital)
Valley View Creek	
*	(Valley View Golf Course)
Hill Brook	
State Run	
(State Street)	(State Street)
Trinity Run	
Holy Run	
(Holy Trinity Cemetery)	(Holy Trinity Cemetery)
Green Run	
(Green Valley Road)	(Green Valley Road)
Lost Knob Brook	
(Lost Knob)	(Lost Knob)
Fork Run	
Fall Run	
Falling Run	Falling Run
County Run	
(County Infirmary)	(County Infirmary)
Silver Creek	Silver Creek
Town Run	
Grace Run	
Land Run	
(Graceland Cemetery)	(Graceland Cemetery)
Slate Run	Slate Run
Tabor Run	
(Mt. Tabor Road, School)	(Mt. Tabor School, Church)
Flat Run	
Rail Run	
(Monon Railroad)	(C. I. and L. Railroad)
Blackiston Run	
(Blackiston Mill)	(Blackiston Mill)
Jacobs Creek	Jacobs Creek
Bald Knob Creek	
(Bald Knob)	(Bald Knob)
Jay Run	
Friendship Run	
*	(Friendship Church)
Lewis Branch	Lewis Branch
Chapel Branch	
(Jacobs Chapel School)	(Jacobs Chapel School)
Uphill Run	
Carters Run	
(Carters Hole)	(Carters Hole)
Plum Run	Plum Run
Big Drain	
Mill Creek	Mill Creek
Cane Run	Cane Run
50 named streams	12 named streams

Highway 64, is memorialized in Valley View Creek. Now-vanished schools and churches also have been commermorated in stream names.

Cemeteries come in for their share of dubious glory. Trinity Run and Holy Run apparently were inspired by Holy Trinity Cemetery, and Grace Run and Land Run by Graceland Cemetery. Uphill Run is no doubt a frivolous entry, possibly in contrast to Flat Run nearby, and Jay Run probably was suggested by Jacobs Creek, to which it is tributary. In all, the 1965 edition of the New Albany Quadrangle map contains 50 named streams, compared with 12 on the 1955 edition.

Summary and Conclusions

It is hard to estimate how many spurious names there may be overall. During the years 1958-62, more than 300 new topographic quadrangle maps of Indiana appeared, and as a first estimate, based on the examples given here, as many as 10,000 such names might be expected. This estimate probably is high by a factor of 2 or 3, however, because in northern Indiana many of the smaller streams have been ditched and in the process have been given legal names through court action. (The main problem with this process is that when the ditch needs to be re-dredged, it is likely to get a new name — the name of the new petitioner). For example, on the 1960 edition of the Greentown Quadrangle, Tipton and Howard Counties, 19 of the 35 named streams are ditches, and only 8 names are likely to be spurious.

Still, even as many as 3,000 fictitious names would be a very large number, and to ensure their removal from the maps or their replacement by valid names would require a very large program of field and library investigation. No such study is recommended here, but it would be wise for map users to realize that many, many names on some of these otherwise authoritative and accurate maps are not valid and are unknown to residents of the mapped areas.

If there is a moral to this tale it is this: geographic names are best established by local usage, not by agency fiat, and the validity of geographic names commonly must be determined in the field or from historical or legal records.

Note

[1] Publication authorized by the State Geologist, Indiana Geological Survey.

HISTORY OF SCIENCE

Chair: Barbara A. Seeley
805 Hastings Terrace
Valparaiso, Indiana 46383 (219) 465-1948

Chair-Elect: N. Gary Lane
Department of Geology
Indiana University
Bloomington, Indiana 47405 (812) 335-7994

ABSTRACT

Chemistry at Indiana Asbury-DePauw in the Nineteenth Century. Donald J. Cook, Department of Chemistry, DePauw University, Greencastle, Indiana 46135.——In the year 1838-39 President Matthew Simpson taught the first course in chemistry at Indiana Asbury University. One of his two students was Charles Gibbs Downey of New Albany who completed his studies at Wesleyan University in 1840. He returned to Asbury as an instructor in mathematics in 1841 and in 1842 became Professor of Natural sciences. William C. Larrabee became Professor of Mathematics. In 1849 Joseph Tingley, an Asbury graduate of 1846 and a cousin of President Simpson was appointed Professor of Natural Sciences and Charles Downey was transferred to the Indiana Central Medical College in Indianapolis, a school within the Indiana Asbury University. This school survived only three years and Downey became Professor of Mathematics at Indiana Asbury in 1852.

Philip Schaffner Baker replaced Tingley and from 1874 until 1882 was responsible for shaping the new department. Indiana Asbury became DePauw University in 1884 and Baker continued as Professor of Chemistry until 1901.

The Richard Owen Geological Survey of Indiana, 1859-1860

N. Gary Lane
Department of Geology
Indiana University
Bloomington, Indiana 47405

Introduction

In this day of four-wheel drive vehicles, freeze-dried foods and motels, it is hard to imagine the day-to-day existence necessary to undertake an extended geological survey of a large area 120 years ago. The difficulties of travel, and procurement of food and shelter, were very different from the amenities that the field geologist takes for granted today. We cannot usually learn about the details of field work by early geologists through study of their published scientific reports, which are the primary aim and ultimate result of the field studies. These reports invariably dwell on the geological phenomena observed, not on the field experiences of the observers.

The Richard Owen survey of Indiana in 1859 and 1860 provides an opportunity to gain insight into the working operations of such a field survey, for two reasons. First, one of Owen's original field notebooks for 1859 is preserved in the Indiana State Library, and provides a detailed account for about 23 days of that survey (1). Second, in 1861 the General Assembly of Indiana published rather detailed expense accounts and vouchers submitted by David Dale Owen (1807-1860) for most of the survey field work of 1860 (2). These accounts permit us to glimpse some of the daily activity of the survey party that would otherwise be lost.

The first geological survey of Indiana was undertaken by David Dale Owen in 1837 and 1838 (3). For the next 20 years the State did not sponsor any geological studies of significance. In March , 1859, a second field survey was approved and $5,000 was appropriated for field expenses and salaries. David D. Owen was asked once again to head this survey. He agreed, on condition that field work would be undertaken by his younger brother, Dr. Richard Owen (1810-1890), who had just returned to New Harmony after teaching for nine years in Tennessee. At that time David Owen was occupied with completion of reports on the geology of both Arkansas and Kentucky, for which states he had served as State Geologist. David Dale Owen died 13 Nov. 1860, after the field work for the second survey of Indiana geology was completed. Richard Owen subsequently, in 1862, was appointed State Geologist of Indiana.

The field surveys by Richard Owen in 1859 and 1860 are of special interest for several reasons. The plan by which the field work was undertaken, combining as it did use of the newly established rail network in Indiana for initial reconnaissance, followed by more traditional horse-and-buggy field work, places this survey at a transition point between old and new ways of conducting field studies. The objectives of the survey were several. Owen was to conduct a thorough survey of the coal fields of Indiana, the soils of the State were to be analyzed, information was to be gathered on milk-sickness, iron ore was to be sought and the gold region of Brown County examined. In addition, the site for the new State prison at Michigan City was examined, as were harbor facilities, at the request of the governor. Finally, a collection of rocks, minerals, and fossils, obtained during the survey were labelled and arranged in the State House. All of this was to be accomplished in about 18 months, for no more than $5,000, with a "strict regard for economy." Amazingly, Richard Owen did fulfill virtually all of these objectives, the major omission being that he did not solve the mystery of milk sickness (4).

Plan and Route of the Survey

During the summer of 1859, when Richard Owen knew that he would be responsible for all survey field work, he clearly made careful plans as to how the survey would be conducted. The nature of the work was conditioned by several practical considerations that had little to do with geology. The State Board of Agriculture was the administrative unit in charge of the survey. This board stipulated that the survey must include each of the 16 agricultural districts into which Indiana was then divided. Thus Owen would have to visit all parts of the State. In order to accomplish the survey he had the Fall field season of 1859 and the Spring, Summer and Fall of 1860. Consequently Owen started field work with three constraints of time, money, and area to be covered. Given these limitations, the best that could be hoped for was a broad overview of Indiana geology and Owen appropriately called his final report a reconnaissance.

Owen began the field work from his home in New Harmony on 19 Sept. 1859. He started with an 18-day trip through those counties of southwestern Indiana that are adjacent to the Ohio River and were not then served by railroads. He was accompanied on this initial phase by his son, Horace P. Owen. They returned to New Harmony on 8 Oct. Richard then began a whirlwind tour of the State, utilizing wherever possible the rapidly expanding rail network, thereby allowing him to make fast, efficient coverage of all 16 agricultural districts. From 8 Oct. to 10 Nov. it is not possible to trace his exact route of travel, but he did start this initial phase in the northernmost part of the State and gradually worked his way south as cooler weather prevailed. The only specific place that he mentions in the final report is that he was in Goshen, Indiana sometime during October, 1859 (5). In the northeastern corner of the State he was able to pay only a brief visit to DeKalb and Noble counties and he "saw little" of Fulton and Starke counties. By 10 Nov. he was in Indianapolis and bought a new field notebook, the one now preserved in the Indiana State Library. This contains a detailed itinerary from 10 Nov. to 3 Dec., when he arrived back in New Harmony. During this time he went to Richmond from Indianapolis, then Liberty, Newcastle, back to Indianapolis, then to Greensburg, Lawrenceburg, Rising Sun, Madison, Jeffersonville, Rockford, Bedford, Bloomington, Greencastle, Terre Haute, Vincennes, Shoals, and Princeton. He traveled a minimum of 700 miles in 24 days, thus averaging almost 30 miles a day. This does not include side excursions out from each stop to look at various geological features. He had a contact at each stop who accompanied him to local sites of interest. Four days, two in Greensburg and one each in Bedford and Greencastle, were spent exclusively on geology, so he travelled more than 30 miles a day. The longest daily trip he made was on 14 Nov., when he traveled by rail from Richmond to Indianapolis, presumably changed rail lines and then went to Greensburg, a total of about 125 miles. The second longest day of travel he spent was 29 Nov. when he went from Terre Haute to Vincennes to Shoals, a distance of about 95 miles, the latter part of the trip by buggy. It is clear that it was possible to move about Indiana quickly and effectively in 1859.

Although Owen used the rails wherever possible, and had undoubtedly planned his route to take full advantage of existing railroads, he was occasionally obliged to resort to that old stand-by, a horse and buggy. There was no rail service from Lawrenceburg through Rising Sun and Madison to Jeffersonville in 1859 and he must have travelled by road, still averaging close to 30 miles per day.

One is tempted to ask, how could the man do any real geological field work, given the amount of time and effort he spent getting from one place to another? This question is answered by two features of his trip that are clearly exemplified by his field notebook and final report. Owen took notes almost continuously while travelling. He noted details of vegetaion, crops, and dominant forest trees, drainage and topography, and even rock outcrops in railroad cuts as the train passed along. Secondly, at each place he stopped he had one or more local contacts, either men that he or his brother knew, agricultural agents, or worthy citizens with whom he had probably made contact prior to his arrival. These men guided him to local features of geological interest and he also took notes from them on various geological phenomena that he was unable to visit. It is clear that he planned to, and did, visit many of these reported features during the next field season. In this way, Owen was able to accumulate a remarkable amount of pertinent information concerning a large area in a brief period of time.

Owen also, in this preliminary reconnaissance as well as in the more extended survey of 1860 did a good job of keeping his political fences mended. He tried to visit the district commissioners for the State Agricultural Board within each of the 16 districts. These and other State political figures who provided assistance to him are mentioned prominently in his final report. It seems clear that Owen hoped, and was planning for, a continuation of the survey after the initial appropriation was ended. The start of the Civil War in 1861, Richard Owen's service in that conflict, and the death of his brother, David Dale, all combined to set aside any hope of continuity in geological studies in Indiana for several years. The next geological Survey funded by the State was in 1869 when E.T. Cox was appointed State Geologist.

On his return to New Harmony in December, Owen had printed 1500 circulars that presumably were mailed to various people and institutions around the State, seeking information concerning the geology of local areas. He also addressed a list of questions and requests to all members of the State Board of Agriculture, a draft of which is in back of 1859 notebook. By the following Spring he was ready to set out on his 1860 survey, which he divided into Spring and Fall surveys. The hottest period of the summer from 2 July until 20 Aug. were spent in New Harmony.

The Spring survey began 9 Apr. and the first six weeks was devoted to a survey of the coal-bearing strata of western and southwestern Indiana. To assist in the survey, Leo Lesquereux, the foremost coal measures paleobotanist of the period, came to New Harmony from Columbus, Ohio and took part in the survey, along with two sub-assistants, E.T. Miller (6) and Charles Randolph. We know that on 4 May they were in Brazil and at Wheatland on 12 May, returning to New Harmony on 19 May, at which time Lesquereux returned to Ohio.

The second phase of the Spring Survey began on 21 May, with Horace P. Owen joining the field party as an assistant. They went first to Evansville, where samples were shipped to Indianapolis, then east to Wyandotte Cave (or Rothrock's as it was then called) in Harrison County, where they spent several days surveying the cave. A map of the cave serves as the frontispiece to Owen's geological report and he included a lengthy discusion of the cave in his report on Harrison County. On 28 May the field part turned northward, arriving in Hendricks County, just west of Indianapolis on 8 June. On 9 June they continued north and spent 14 June at Delphi, 15 June at Logansport, and 16-17 June near Peru. During this interval they were averaging about 20 miles a day with a wagon and buggy, in addition to time spent on geology and camp chores. From Peru they swung southeastward in a arc through Marion, Alexandria, and Anderson, arriving at Noblesville on 21 June. Thus, Howard and Tipton counties were bypassed, as they also had been in the 1859 survey. In the vicinity of Peru Charles Randolph left the field party, because he was paid wages from 9 April to 16 June. Miller and the two Owen men continued southward across the State during the latter part of June, although no dates are known when they were at specific localities. They arrived back in New Harmony on 2 July and stayed there until 20 August, then they set out for the Fall survey.

No evidence is available for the route of the field party during the last 10 days of August or for early September. On 13 September, however, they were at Columbia City, in the northeastern part of Indiana. They had made good progress diagonally across the State from southwest to northeast during that 24 day interval. They then, or shortly after

13 September, turned southeast through Portland, Winchester, and Milton to Connersville, where they spent 19 September. At this point, one of the field party presumably became ill. Owen says that he had intended to visit Jennings and Washington counties during this Fall survey, but was prevented from doing so because of the illness of one of the survey party. In the detailed field expenses for the survey Owen spent $2.80 for medicine in Connersville, presumably for the sick member of the party. They immediately started back for New Harmony at a rapid rate. They were in Shelbyville the next day, 20 September, in Brown County the next day, and arrived back in New Harmony on 26 September.

One final phase of the field work remained to be completed. David D. Owen, in the initial planning for the survey, had retained Joseph P. Lesley of Philadelphia to make a detailed topographic and geologic map of Perry County, to serve as a model for the kind of detailed geological work that both Owen brothers beieved was needed by the State (7). Richard Owen did not accompany this topographical survey, which took place from 26 September to 17 October. Lesley was accompanied in the field by another Owen brother, Alfred Dale, and by a camp tender, Jesse Mathews. Richard Owen remained in New Harmony to work on his geological report.

This brought to an end the field work for the survey. Richard Owen had coverd a large part of the State, some parts more than once, within 18 months. He had visited 85 of the 92 counties in the State, as well as undertaking assorted tasks assigned by the Governor or by the State Board of Agriculture. He surely began writing the final report immediately, but events were to provide serious interruptions to this work. The death of his brother, David Dale, in November, and the start of the Civil War in April, 1861, surely impeded his work. By June of 1861, when galley proofs of the final report became available, Richard Owen was serving in the army at Camp Tippecanoe in northern Indiana, and his final report was issued the next year, in 1862.

Logistics of field work in Indiana in 1860

We have noted above the way in which Owen and his assistants were able to move rapidly about Indiana in 1860. One is led to speculate on what their day-to-day life was like in their constantly moving camp. The detailed expense accounts published by the State after completion of the survey provide some clues as to the daily routine of the field party. They presumably slept outdoors at all times, becaue no expense items are listed for rooms during the entire 107 days period of the Spring and Fall surveys, and only one instance of meals being purchased is listed, when they bought four suppers for a total of $1 on 7 September, somewhere between Lafayette and Columbia City. Richard Owen bought a buffalo robe, for $6, that he presumably slept on or under, and they surely carried a tent for rainy weather. At least one county, Henry, was visited only briefly because of very heavy rains, according to the final report. It seems clear from the expense acounts that a great deal of time, trouble, and expense was caused by the vehicles and animals that they used for transport, as well as the rapid pace they set and the condition of the roads. This account will focus on two aspects of field existence that are most clearly brought out by the published expense accounts: the diet of the party, and the expense and care of their transport.

Each time the survey party left New Harmony they surely were well-provided with staple items of food that they gradually used up during the field work. These items are not listed separately in the expense accounts except in one case, on 19 May, when they were about to set out from New Harmony for seven weeks. In addition to a bill of $14.98 for groceries, they paid $7 for pilot bread, $5.10 for hams, $1.50 for coffee, 50 cents for tea, and $3.25 for eggs, sugar, molasses, etc. Despite these purchases they bought, at Evansville two days later, butter (40 cents), dried fruit, $1, bread for 25 cents, tea (90 cents), and another ham for $3 (8). They must have carried sufficient flour and salt for the entire field period, as no purchases of these items are listed.

During the 84-day period of the Spring survey, from 9 April to 2 July they spent a total of $44.07 on food while traveling, which averages 53 cents a day to feed four healthy, hard-working men. Items purchased along the way, with the total amount spent for each, are listed below, in order to decreasing amount of money spent:

Eggs, $7.33; butter, $6.98; bread, $5.75; sugar, $5.10; ham, $4.00; milk, $3.00; tea, $2.80; molasses, $1.40; dried fruit, $1.40; cheese, $1.20.

Other items, each of which consists of a single purchase, include a chicken, 25 cents; a pheasant (?grouse or prairie chicken), 10 cents; a shoulder of meat, $1.75; vinegar, 35 cents; beef, 20 cents and unspecified meat, 26 cents. On the same day that they bought the shoulder of meat, they also bought a saw, perhaps to cut up the meat; and two days later they bought vinegar for the only time, perhaps to help preserve meat not yet consumed. In one instance the account mentions that they bought six loaves of bread for 25 cents. If that were the standard price then they bought 138 loaves on the Spring survey, in addition to the $7 worth of pilot bread that they carried with them from New Harmony. This amounts to about 1½ loaves of fresh bread a day for the four men.

Their daily menu must have been monotonous, consisting principally of eggs, bread and butter, and tea, coffe or milk for breakfast; bread, butter, and cheese for lunch; and ham, bread, butter, and milk or tea for dinner, with stewed dried fruit for dessert. Seemingly the main variations on this menu were the occasional addition of fresh fruits or vegetables and substitution of fowl or beef for ham. On one occasion they purchased cream of tartar, an essential ingredient, with baking soda, of baking powder. They may have made biscuits, skillet bread, pancakes or fired cornmeal mush and used their considerable purchaes of molasses over these bread goods.

During the Fall survey of 1860, when they were gone from New Harmony for 35 days, their food purchases were somewhat different and more varied than in the Spring, and rather surprisingly did not include a single purchase of milk, whereas milk was purchased daily or every two days during the Spring. The food expenditures, in order or amount of money spent, are:

Eggs and butter, $8.02; bread, $4.40; sugar, $4; one ham, $2.25; chocolate, $1.10; molasses, $1.25; tea, $1.00; melons, 60 cents.

In addition, they made one purchase of vegetables for 20 cents, one of potatoes for 15 cents, and one of apples for 10 cents. Their average daily expenditure was somewhat higher than in the Spring, being about 66 cents per day for the entire field party.

Some food items, especially tea and sugar, were relatively quite expensive. In only one instance did the party pay less than a dollar for sugar. Hams seemingly ranged from two to three dollars each, and, during the Spring survey, milk was invariably purchased for a dime, presumably for a bucketful. The party may have stopped milk purchaes in the Fall because of the prevalence of milk sickness, a malady then of unknown cause that was one of the items the survey was to investigate. There was general belief that certain mineral springs caused the illness, which was passed on through the milk of the cow. It is now known that the sickness is a poison contained in snakeroot and other plants eaten by cows.

One cannot rule out the possibility that the field party may have augmented their purchased food with game or fowl that they shot along the way. In two instances they bought powder or powder and shot that was presumably used for this purpose. Richard Owen, in the final report, notes that they captured a large bullfrog for camp provisions in Miami County and that they commonly shot, for camp use while in Benton County, the pinnated grouse and wild (passenger) pigeons.

For transportation the field party moved about with a wagon, two mules, two horses (one named Jim), a buggy and a carriage. All but the buggy and Jim belonged to David

Dale Owen, who rented the equipment and animals to the State for the field work. Jim and the buggy were purchased in New Harmony for field work, and presumably were later sold after completion of the survey. Owen charged the State $1.50 per day for use of two mules, one horse, wagon, carriage and camp equipment, surely a reasonable price.

Food for these animals was purchaed almost daily during the field season, consisting chiefly of corn and hay, but also including oats, fodder, and in one case, Hungarian hay. Corn was obtained for 40 to 65 cents a bushel and oats for 38 cents a bushel. During the entire survey the cost of food for four men and for four animals was approximately the same, sometimes one being a little higher, sometimes the other. A tabulation of comparative costs is given below.

	Cost of food for field party	Cost of food for animals
April—21 days	$10.05	$11.55
May—31 days	$18.43	$18.65
June—30 days	$15.59	$20.85
August—10 days	$6.65	$5.95
September—26 days	$19.47	$17.40

In addition to food, the party was constantly stopping to have the shoes repaired or replaced on one or more of the animals. In the Spring survey they presumably set out from New Harmony with the animals well shod. During 21 days in April they only had to have one shoe repaired, for 15 cents. In May the cost of shoeing increased to $1.75. In June, they spent $3.02 for shoeing. The same pattern is evident in the Fall survey. During the last 10 days of August they spent 50 cents to have one mule re-shod, but in September they listed five separate shoeing costs for a total of $1.55. In addition to these costs they had to buy new mule collars, have the wagon or buggy repaired five times, and buy new, or have mended, linch pins, harness, sircingle, hames, singletree, a bolt, chain, lapring, and straps.

Shortly after setting out from New Harmony in April, they incurred an expense of $4.00 for "expenses on a stray horse and mule, already advertised." Presumably the animals wandered off during the night, and a reward of $4 was advertised for their return. One can imagine that one of the sub-assistants was reprimanded for allowing the aninamls to stray.

In addition to the time and expense spent taking care of the animals and vehicles, the party was also obliged to spend a rather surprising sum for ferriage and toll road charges. During the Spring survey they used a ferry three times in April, for 50 cents each time. In May they paid $1.40 for ferries and $2.05 to use six toll roads. In June they again used three ferries, for $1.20, and 10 toll roads for $2.99. In the Fall survey they used a ferry four times for $2.10 and toll roads 11 times for $2.84. Most of the ferry charges were presumably for crossing larger rivers, such as the Wabash or one of the branches of the White River. Ferry charges were usually 50 cents, although sometimes the amount was 10 cents more or less than that amount. Toll road charges were extremely variable, ranging from a high of 60 cents to a low of four cents, presumably depending on the length of the toll road and its condition.

The party incurred relatively minor expenses in connection with their geological studies. These consisted mainly of buying wooden boxes in which to store and ship rock and fossil specimens. The boxes ranged from 15 to 35 cents each. Paper for wrapping the specimens was quite expensive, each purchase averaging about one dollar. Nails, pencils, and new field notebooks were the only other such expenses.

Personal expenses for the party included such items as oil, presumably coal oil for lanterns; candles, soap, a teapot, tin bucket and cups, postage stamps and envelopes, and one instance of having their washing done for 59 cents. An additional personal expense is listed as a 3 percent discount on a draft, the discount amounting to $2.25. This was paid on 25 June, after the field party had been in the field for over a month, and a week before they returned to New Harmony. Presumably Richard Owen expended all cash on hand and had to write a check for about $70 in order to continue on to New Harmony. Bank charges for this service have decreased markedly in the intervening years.

In summary, the Richard Owen surveys of 1859 and 1860 were well-planned and executed, keeping in mind the various objectives that they sought to fulfill. The ability of the geologists to move about the State, both by train and by road, was surprisingly good. The daily diet of the field party was restricted in variety, and by present day standards would be judged monotonous and not very nutritious. It is also clear that care of vehicles and animals was a constant source of trouble and expense.

Literature Cited

1. Richard Owen's second field notebook for the Fall survey of 1859 is in the manuscript collection of the Indiana State Library, Indianapolis. The notebook covers the period from 10 Nov. to 3 Dec., 1859.
2. Documents of the General Assembly of Indiana at the forty-first session, part II; Condensed report of the geological and agricultural survey of the State of Indiana for 1859 and 1860, p. 163-189, 1861.
3. Richard Owen. 1862. Report of a geological reconnaissance of Indiana, made during the years 1859 and 1860, under the direction of the late David Dale Owen, M.D. 368p. H.H. Dodd & Co., Indianapolis.
4. In the expense accounts and vouchers, this assistant's middle initial is variously given as T, I, and J.
5. Richard Owen. 1862. *op cit.*, p. 199.
6. E.T. Miller.
7. Lesley's topographical map of Perry County was never published. The original map was framed and hung in the State Capitol building by Richard Owen, but, by 1916, had disappeared. See W.S. Blatchley. 1917. A century of geology in Indiana. Proc. Indiana Acad. Sci. for 1916, p. 123.
8. At this time (1859) sugar was advertised for six to seven cents per pound and coffee from 11 to 12 cents per pound in the Evansville Daily Journal. Interestingly, land in Missouri was advertised in the same newspaper for 12½ cents per acre.
9. Richard Owen. 1862. *op cit.* p. 73, 221.

Fernandus Payne, Educator and Scientist

FRANK N. YOUNG
Department of Biology
Indiana University
Bloomington, Indiana 47405

Fernandus Payne (1881-1977) became chairman of zoology and dean of the graduate school at Indiana University in 1927, and served in those offices for more than 20 years. He was also, for a brief period, dean of the college of arts and sciences. yet during this long period of multiple duties in administration, he managed to carry on a productive and important program of research. He sometimes spent as much as six hours a day in his laboratory doing cytological or other types of work which may have led him to remark that he couldn't understand why some people thought college teaching was an easy job. This research, of course, was in addition to his other duties.

On leaving Indiana University in 1963, Salvador E. Luria, later Nobel Laureate, wrote Dean Payne, in part, as follows: "I am sincere in saying that the things that have been pleasant during my eight years with I.U.—and they have been the great majority—have been the product of what I have called the Payne spirit, something difficult to define but which has to do with consciousness of being in the main path out of mediocrity, a feeling of appreciation for what is relevant and of impatience for what is trivial. This I consider the essential thing in science, and you have shown me that it is also the main thing in administration. Looking back, I can see that what made I.U. an enjoyable place to me was the sense of recognition emanating, often imperceptibly, from the Dean's office in Biology Hall, a sort of shield and defense for the striving beginner against mediocrity and narrow-mindedness." (Memoirs and Reflections, 1972, pp. 130-131).

Fernandus Payne came to begin study at Indiana University by a devious path involving hard labor with a series of late 19th Century Indiana farm families, teaching in country schools, and finally attending a private normal school in Valparaiso, Indiana. From I.U. he went to Columbia University where he earned the Ph.D. degree with E.B. Wilson and T.H. Morgan in a then record two years time. From Columbia he returned to I.U., foregoing a prestigious postdoctoral fellowship at Johns Hopkins University. He remained at I.U. until his retirement in 1951, and continued his research in Bloomington until he reached the age of 90. Even after leaving Bloomington, howver, he continued to write and prepared his Memories and Reflections (1972) and at least one technical paper which seems to have been lost.

Payne had several things going for him, perhaps the most important of which were his absolute honesty and his capacity for hard work. He was a man who believed in precision, but not in nit picking and trivialities. He did a great deal with the minimal educational background he managed to acquire before coming to I.U. as a student in 1902. He became not only a master administrator, but was a true scientific scholar. He remarked that he had worked with a variety of things, and perhaps would have done better to specialize, but then he really enjoyed his work both in education and biology. Perhaps one did not need to be a genius to get along with Payne, but I am sure Luria was right in recognizing his uncompromising attitude toward mediocrity and narrow-mindedness.

David Starr Jordan had instilled in his students at I.U. an interest in and respect for scientific research. Since there was no graduate school until late in the 19th Century, it was undergraduate students who received this message. A number subsequently went on to do significant research in later years. Carl H. Eigenmann continued Jordan's emphasis upon reserach. Thus, even as an undergraduate Payne was induced to begin a program of study of the eyes of a blind Cuban lizard (published 1906). These early cytological studies were refined over his lifetime, ending with elegant electron microscope studies of the pituitary of the white Leghorn fowl.

During his graduate years at Columbia, he undertook two lines of research—one cytological on the chromosomes of *Gelastocoris*, a small semi-aquatic bug, and another on the effects of darkness on behavior and vision in *Drosophila*. The first of these resulted in the first demonstration of multiple X-chromosomes, and the second, a classical refutation of Lamarckian theory of evolution, in the introduction of *Drosophila* as a tool in research. Payne had taken the original stock of *Drosophila* with him to Columbia, and Morgan soon adopted it for his own research. Later Payne studied the inheritance of bristle number in *Drosophila* and even made studies of the effects of X-rays on inheritance in various invertebrates including *Drosophila*. Unfortunately, the latter experiments were inconclusive. Later H.J. Muller, using much the same techniques, demonstrated the mutational effects of X-rays for which he received the Nobel Prize. Later (1924) Payne published a paper describing the effects of chromosomal inversions (the Payne inversions) in *Drosophila*.

Payne admitted that he was a somewhat erratic researcher in the sense that he did not confine his interest to the head of the pin but worked widely in several fields of biology. His research with genetics at Columbia resulted in his introducing its study at I.U. despite the opposition of some of the "old guard." In cytology, he made a number of significant discoveries. The presence of multiple X-chromosomes in bugs (Hemiptera) ws one, and he also demonstrated in the mole cricket, *Gryllotalpa*, that animals with very different chromosome complements might be morphologically indistinguishable. His extensive collection of slides of chromosomes of bugs and other insects remains at I.U. and may still produce knowledge in the future. He once told me that he had no interest in making a catalog, but was mainly looking for novelties. He also did pioneer work on the structure of the insect egg, and was among the first to recognize the involvement of the mitochondria with the nuclear material during spermatogenesis.

Payne was one of the first workers to recognize and describe the hydroid stage of the world-wide freshwater jellyfish, *Craspedacusta*. He also (1926) described one of the earliest human embryos known. His study of the latter embryo resulted in the production of a wax model by the workers at the Carnegie Laboratory in Washington.

Payne's most important work was probably with the endocrine glands of the fowl. In later years he defined the effects of aging in various endocrine glands in the fowl. He recognized the importance to cytology of the electron microscope, and taught himself to use that instrument after he was 70 years old. In 1949, when I first came to I.U., he was actively engaged in the study of the effects of aging on these glands. In cooperation with William R. Breneman, he was assaying the glands of a number of aged birds. These kept arriving from all over the United States, and I cannot say that any of them would have won an elegant fowl award. Some had very few feathers and other peculiarities associated with old age.

Eric L. Simmons, who received the Ph.D. from I.U. and only recently retired from the biology department of the University of Chicago, came to I.U. on an assistantship to work with Dean Payne in his cytological work. Payne had just returned from the Carnegie Laboratory on the Tortugas off Florida and was interested in studying *Ptychodera* which he had collected and fixed for sectioning. Eric says he worked really hard on preparing the material, but Payne made no comment until one day when Eric was in the cubbyhole behind the Dean's office he had been given to work in, he accidentally heard Payne talking to Breneman in the other room. Payne said, "Look at the cells in these slides. Simmons is doing a magnificent job!" Later Breneman, in his characteristic manner, clapped Eric on the back and said Payne thought he was doing a good job. Eric allowed that he wished Payne would tell him what he thought of his work. Breneman responded, to the effect "Oh, you'd know if he didn't like your work. With his last assistant he would sit next door and throw the slides that he wasn't pleased with into the corner."

The attached bibliography represents the life work of Fernandus Payne in the biological sciences and most of his writing on education and its administration. An Indiana farm boy transformed himself thorugh hard work and honesty into an eminent scientist and a master administrator.

Bibliography of Fernandus Payne

1906. The eyes of the blind vertebrates of North America, VII. The eys of *Amphisbaena punctata*, a blind lizard from Cuba. Biol. Bull. 11:60-67 (Zoology Contribution #77).

1907. The reactions of the blind fish *Amblyopsis spelaeus* to light. Biol. Bull. 13:317-323 (Z.C. #89).

1908. On the sexual differences of the chromosome-groups in *Galgulus oculatus*. Biol. Bull. 14:297-303.

1909. Some new tyes of chromosome distribution and their relation to sex. Biol. Bull. 16:119-168.

1909. The separated blastomers of centrifuged eggs of *Arbacia*. Sci., N.S. 30:934-935.

1910. The chromosomes of *Acholla multispinosa*. Biol. Bull. 18:174-179 (Z.C. #111).

1910. Forty-nine generations in the dark. Biol. Bull. 18:188-190 (Z.C. #112).

1911. *Drosophila ampelophila* bred in the dark for sixty-nine generations. Biol. Bull. 21:297-301 (Z.C. #120).

1912. A further study of the Reduviidae. J. Morph. 23:331-347 (Z.C. #124). II. The nucleolus of the young oocytes and origin of the ova in *Gelastocoris*.

1912. The chromosomes of *Gryllotalpa borealis*. Archiv fur Zellforshchung 9:141-148 (Z.C. #126).

1913. A study of the effect of radium on the eggs of *Ascaris megatocephala univalens*. Archiv Entwickenlungsmech. d. Organismen 34:287-293.

1914. Chromosomal variations and the formation of the first spermatocyte chromosomes in the European Earwig, *Forficula* sp. J. Morph. 25:550-585 (Z.C. #134).

1916. A study of the germ cells of *Gryllotalpa borealis* and *Gryllotalpa vulgaris*. J. Morph. 28:287-327 (Z.C. #153).

1918. The effect of artificial selection on bristle number in *Drosophila ampelophila* and its interpretation. Proc. Natl. Acad. Sci. 4:55-58.

1918. An experiment to test the nature of the variations on which selection acts. Ind. Univ. Studies, Vol. 5, No. 36, pp. 1-45.

1920. Selection for high and low bristle number in the mutant strain *reduced*. Genetics 5:501-542 (Z.C. #173).

1921. The heredity of orange eye color in *Drosophila*. Am. Nat. 61:377-381 (Z.C. #182).

1922. (with M. Denny). A gynandromorph in *Drosophila melanogaster*. Am. Nat. 61:383-384 (Z.C. #191).

1924. A study of the fresh water medusa, *Craspedacusta ryderi*. J. Morph. 38:387-430) (Z.C. #199).

1924. Cross-over modifiers in the third chromosome of *Drosophila melanogaster*. Genetics 9:327-342 (Z.C. #200).

1925. General description of a 7-somite human embryo. Carnegie Inst. Wash. Pub. Cont. Emb. 81:115-124 (three plates) (Z.C. #201).

1926. Further studies of the life history of *Craspedacusta ryderi*, a fresh water Hydromedusan. Biol. Bull. 50:433-443 (Waterman Contrib. No. 22) (Z.C. #211).

1926. Some cytoplasmic structures in the male germ cells of *Galastocoris oculatus*. J. Morph. Physiol. 43:299-345 (Waterman Contrib. #) (Z.C. #218).

1932. A study of the cytoplasm in insect ova. J. Morph. 53:523-591 (Waterman Contrib. #62) (Z.C. #229).
1931. The problem of the number and variety of graduate courses in education. Proceedings of the Association of American Universities, pp. 80-87.
1933. (with W.B. Munro and H.L. Dodds). Part III: College and University Teaching, pp. 36-103. Published by the American Association of University Professors as a special supplement (86 pages).
1934. Admission policy of Graduate Schools with reference to the "accepted list."
1935. (with E. Spieth). An open letter to college teachers. Principia Press, Bloomington, Ind., 380 pages.
1936. Early development of *Ptychodera bahamensis.* Carnegie Inst. Wash. Publ. 475:71-76 (Tortugas Lab. Papers #31) (Z.C. #246).
1937. Genetics and Evolution. Sigma Xi Quarterly 76:131-140.
1940. "Signet-ring" or "castration" cells in the chick. Anatom. Record 76, 8 pages. January 25, 1940 (Z.C. #280).
1940. *Graduate Education*. Read before National Society of Animal Production and published in their Journal.
1941. *Graduate Work—The Future*. Read at the 25th anniversary of the Establishment of the Graduate Faculty at Iowa State College. Iowa State College Bull. 39, No. 44, pp. 56-67.
1942. The cytology of the anterior pituitary of the fowl. Biol. Bull. 82 (1):79-111 (Z.C. #300).
1943. The cytology of the anterior pituitary of broody fowls. Anat. Rec. 86 (1):1-13 (Z.C. #316).
1944. Anterior pituitary-thyroid relationships in the fowl. Anat. Rec. 88 (4):337-350 (Z.C. #326).
1946. The cellular picture in the anterior pituitary of normal fowls from embryo to old age. Anat. Rec. 96 (1):77-91 (Z.C. #356).
1947. Effects of gonad removal on the anterior pituitary of the fowl from 10 days to 6 years. Anat. Rec. 97 (4):507-518 (Z.C. #362).
1949. Changes in the endocrine glands of the fowl with age. J. Gerontol. 4 (3):155-159 (Z.C. #399); (3) 193-199, 10 figs.
1950. Teaching of Science at the College Level. Science, 111, (2892):589-594.
1952. (with W.R. Breneman). Lymphoid areas in endocrine glands of fowl. Poultry Sci. 31:155-165 (Z.C. #438).
1952. Cytological changes in the cells of the pituitary, thyroids, adrenals, and sex glands of aging fowl. Chapter 16 in Cowdry's Problems of Aging, 3rd ed., pp. 381-401.
1952. Do mitochondria divide? J. Exp. Zool. 91:555-567 (Z.C. #489).
1955. Adrenal ganglia and medullary cells in hypophysectomized and aging fowl. J. Exp. Zool. 128:259-290 (Z.C. #569).
1955. Acidophilic granules in the gonadotropic secreting basophiles of laying hens. Anat. Rec. 122:49-56.
1957. A cytological study of the thyroid glands of normal and experimental fowl, including interrelationships with the pituitary, gonads, and adrenals. J. Morph. 101:89-130 (Z.C. #577).
1959. Cytologic evidence of secretory activity in the neurohypophysis of the fowl. Anat. Rec. 134 (3):433-454, 52 figs. (Z.C. #666).
1961. The pituitary of the fowl. A correction and addition. Anat. Rec. 140 (4):321-328 (Z.C. #702).
1965. Some observations on the anterior pituitary of the domestic fowl with the aid of the electron microscope. Wistar Institute, J. Morph. 117 (2):185-200 (Z.C. #765).

1966. Some observations on spermatogenesis in *Gelastrocoris oculatus* (Hemiptera) with the aid of the electron microscope. J. Morph. 119 (3):357-382 (Z.C. #794).
1972. Memories and reflections—Fernandus Payne, Indiana University, Bloomington, Ind., 1972, 133 pp., illus.

References Including Descriptions and Evaluations of Research by Fernandus Payne

Anon. 1971. Indianapolis Star Magazine, Nov. 28, 1971, pp. 48-52, 3 photographs.
Carlson, E.A. 1985. Payne, Fernandus *in* Dictionary of Scientific Biography, Scribner's.
Meserve, W.J. (editor). 1981. Research and Creative Activity (at Indiana University), Vol. 3:5.
Young, F.N. 1955. Entomology-Work at Indiana University and Other Institutions and by Private Individuals Since 1854. Proc. Indiana Acad. Sci. 64:165-172.
______. 1983. A Brief History of Biology at Indiana University. Proc. Indiana Acad. Sci. Vol. 92:297-312, 1 fig.
______. 1986. The Giants of Zoology. Proc. Indiana Acad. Sci., Vol. 95:371-374.

MICROBIOLOGY AND MOLECULAR BIOLOGY

Chair: Nancy C. Behforouz
Department of Biology
Ball State University
Muncie, Indiana 47306 (317) 285-8844

Chair-Elect: James L. Shellhaus
Butler University
4600 Sunset Ave.
Indianapolis, Indiana 46208 (317) 283-9587

ABSTRACTS

Separation and Characterization of Chitinase and Chitobiase from CDC Group *EF4a*. Sheila M. Bailey and Carl E. Warnes, Department of Biology, Ball State University, Muncie, Indiana 47306.——The separation of the bacterial chitinase/chitobiase enzyme complexes poses problems due to their similar molecular weights and cooperative mode of action. However, application of affinity chromatography and temperature treatments have allowed for effective separation of these two enzymes. Further treatment of concentrated cell-free supernates by column chromatography and SDS polyacrylamide gel electrophoresis (PAGE) indicates that the organism secretes chitinase/chitobiase enzymes of similar molecular weight as that reported in the literature for *Vibrio*, *Streptomyces*, and *Serratia* species but may differ significantly from that of *Aeromonas* species.

Isolation of Mevinolin Resistant Strains in Yeast. M. Bard, A.S. Burnett, L.S. Burrows, Department of Biochemistry and R.A. Parker, Department of Biology, Indiana University School of Medicine, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223.——The drug mevinolin will be used as an anti-hypercholesterolemic drug since it is a competitive inhibitor of the rate limiting enzyme in cholesterol biosynthesis, HMG-CoA reductase. Mevinolin treatment concomitantly results in increased enzyme synthesis; mammalian cells selected for resistance to this drug show greatly increased levels of enzyme activity as well as gene amplification. The ergosterol biosynthetic pathway in the yeast *Saccharomyces cervisiae* is very similar to mammalian cholesterol biosynthesis at least through the formation of lanosterol. We have isolated a number of mevinolin resistant strains and find that our most resistant strain, MV71, does not demonstrate any alteration in HMG-CoA reductase activity. All resistant strains grew better in the presence of mevinolin plus ergosterol than in mevinolin alone. Sterol analyses indicate that MV71 accumulates more total sterol than wild type when grown in the presence of mevinolin. We interpret these results as being due to differential uptake in wild type and resistant strains.

Decreased Survival of *Leishmania tropica* in Macrophages Treated with Cyclosporine A. Nancy C. Behforouz and Charlotte Wenger, Department of Biology, Ball State University, Muncie, Indiana 47306.——Normal Balb/C macrophages were treated *in vitro* with Cyclosporine A (CSA) or medium alone either before, during or after infection with *Leishmania tropica.* Those macrophages treated with CSA had significantly decreased infection rates as compared to control macrophages. A concentration of 1 ug/ml of CSA was effective in inducing a 66% to 95% decrease in numbers of intracellular leishmania depending on the length of exposure to the drug *in vitro.* The decreased survival of the amastigote form may be due either to direct drug action on the parasite or to a drug-induced increase in leishmanial activity of the macrophages. The anti-leishmanial activity of Cyclosporine A described here may be in part responsible for the protective effect which Cyclosporine A has *in vivo* towards this parasite.

Bathocuproine Disulfonate and Interferon: Progress and Prospects. Jay G. Calvert and Edward H. Simon, Purdue University, West Lafayette, Indiana 47907.——Bathocuproine disulfonate (BCS) is a potent and specific chelator of copper ions. The BCS_2Cu (II) complex has a higher redox potential than Cu(II) alone, which facilitates its reduction to the stable $BCS_2Cu(I)$ complex with the concomitant oxidation of a suitable substate. Several mouse interferons are particularly susceptible to this oxidative damage, since addition of millimolar concentrations of BCS to the growth medium of interferon treated cells results in rapid inactivation of residual or cell-bound interferon. Addition of micromolar amounts of $CuSO_4$ potentiates the inactivation of interferon by BCS. Treatment with BCS is not cytotoxic (although prolonged treatment inhibits cell division) and does not inhibit the growth of mengovirus. BCS is at least as effective an anti-interferon antibody at neutralizing residual or cell-bound interferon activity, and has the additional benefits of being less expensive and more readily standardized. BCS may prove to be useful probe for dissecting early events in the course of interferon action.

Location of Sites on Calmodulin that React with a Phenothiazine. Frederick Faust and Harry W. Jarrett, Department of Biology, Indiana University-Purdue University at Indianapolis, Indiana 46223.——Calmodulin is a Ca^{2+}-dependent regulatory protein that activates several enzymes including phosphodiesterase, Ca^{2+}-transport AT-Pase, and NAD kinase. Calmodulin also binds hydrophobic drugs including the phenothiazine antidepressants. Subsequent to drug binding calmodulin is unable to activate enzymes; it has been suggested that the drug-binding and enzyme-binding sites must be near each other in the tertiary structure of calmodulin. A chemically reactive phenothiazine, 10-(3-propionyloxysuccinimide)-2-(trifluormethyl) phenothiazine, reacts 2:1 with calmodulin. Studies of the drug-labelled tryptic peptides have shown that the drug reacts first with Lys_{148} and then subsequently with lysines 21, 75, and 77.

S-Adenosylmethionine Synthetase and Spore Germination in *Mucor racemosus.* Robert Garcia, Ball State University, Muncie, Indiana 47306.——Previous studies, with this dimorphic fungus, have shown that the intracellular concentration of S-Adenosylmethionine (SAM) increases approximately threefold during the aerobic conversion of yeasts to hyphae. The specific activity of SAM Synchetase, the enzyme responsible for the synthesis of SAM, also increased during the conversion in cell type. Subsequent work has shown that this observed increase in SAM is at least, in part, necessary because of an increase in protein methylation.

This study examined the specific activity of the synthetase during a different phase of the life cycle; the germination of the spore under aerobic and anaerobic conditions. Sporangiospores were placed in a semi-defined medium and samples were taken throughout the time period required for aerobic and anaerobic germination. Additionally, experiments were performed with a SAM Synthetase activity inhibitor in order to determine whether methylation is central to the germination process.

Isolation and Identification of *Azospirillum* and *Herbaspirillum* Strains from Soil of Several Eastern States. Edwin M. Goebel, Jenny I. Jockel and James K. Matchuny. Department of Biological Sciences, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——Soil samples were collected from nine sites in the eastern United States. Those sites were rest areas along the interstate highway system in Kentucky and Ohio. One sample was obtained in a national park in Tennessee. Soil was inoculated into an enrichment medium containing malic acid and lacking organic nitrogen at either pH 6.0 or pH 6.8. Further isolation utilized Congo Red agar at either pH. Presumptive isolates were gram stained and speciated via the results from carbohydrate or malic acid utilization in either nitrogen-fixing or fixed-nitrogen conditions. *Azospirillum* and/or *Herbaspirillum* species were recovered from eight of the nine sites.

The Effect of *Azospirillum* and *Herbaspirillum* Inoculation upon the Yield of Winter Wheat (*Triticum aestivum*). EDWIN M. GOEBEL, JAMES J. TOBOLSKI AND DENNIS A. FRIEDLE. Department of Biological Sciences, Indiana University-Purdue University at Fort Wayne, Fort Wayne, Indiana 46805.——The soil of field-grown winter wheat was inoculated with *Azospirillum lipoferum* (strain Sp59b), *Herbaspirillum seropedicae* (strain Z-67) or an autoclaved culture of strain Z-67 (control). The experimental design consisted of seven blocks in which each of the three treatments was completely randomized. Each plot was 2.25 meters square (1.5 m on a side) in size and wsa inoculated with ca. 10^8 microbial cells diluted in 4 liters of water. The inoculations were made on 14 May 1986 just prior to the emergence of spikes. One square meter areas were harvested by hand from the center of each plot on 12-14 July 1986. Seeds were removed from the spikelet by hand, dried and plot seed weights were determined. Approximately a 13% increase in total dry weight was found between control plots and plots inoculated with *H. serapedicae*. This difference was significant at the 0.20 level as determined by a paired T-test. No differences were found between control plots and plots inoculated with *A. lipoferum*. These results are in agreement with other studies conducted in Israel.

Characterization of SPR6, a Sporulation Regulated Gene in Yeast. STANLEY N. GROVE, RICHARD F. IANNACONE, CARMELO A. MILANO AND MARY J. CLANCY, Department of Biological Sciences, University of Notre Dame, Notre Dame, Indiana 46556.——Sporulation in the yeast, *Saccharomyces cerevisiae*, is a model for understanding developmental control of gene expression in higher cells. We have cloned 27 distinct SPR (Sporulation regulated) sequences which can be grouped into early, middle and late transcription classes. We have constructed a plasmid, pRI1, containing the yeast sequence which includes SPR6, a late gene. An extensive restriction map has been developed. The approximate origin of the SPR6 transcript was determined via Northern blot analysis of selected restriction fragments using sporulation poly A mRNA's as probes. The direction of transcription was determined by cloning an internal restriction fragment into M13 cloning vectors to see which form yielded ssDNA complementary to sporulation RNA. This work provides the background for sequencing and gene disruption experiments to determine how expression is regulated.

Dietary Effects of Tannic Acid on the Gut Microflora of Sprague-Dawley Rats. KATHLEEN HARDY, CAROL BRANKA, ELIZABETH WATSON AND KARA EBERLY, Saint Mary's College, Notre Dame, Indiana 46556.——Tannic acid is a naturally occurring polyphenolic compound in many herbivore diets. In vitro tannic acid is inhibitory to many bacteria, especially Gram positive organisms. This study examined the effects of feeding tannic acid (0% to 5%) in a balanced rodent ration on total fecal bacteria and populations of facultative organisms (enterics, enterococci, staphylococci, lactobacilli) in rats. Total bacterial counts, which represent mostly anaerobes, increased with dietary tannic acid, while facultative levels were generally unaffected. These results are compared to similar experiments with red squirrels, whose natural diet is high in tannic acid. (K. Eberly, E. Mould, and D. Duff 1982). Effect of Dietary Tannic Acid on Facultative Gut Microflora of the Red Squirrel. Proceedings of the Indiana Academy of Science *92*: 317-322.)

Synthesis and Characterization of Protein A-silica for High Performance Affinity Chromatography. Larry R. Massom and Harry W. Jarrett, Department of Biology, Indiana University-Purdue University at Indianapolis, Indianapolis, Indiana 46223. ——Protein A from *Staphylococcus aureus* binds nocovalently IgG-class antibodies. This protein was reacted with 5 micron 3-glycidyloxypropyl-silica beads with 1000 angstom pores and was compared to commerical Protein A-Sepharose in the immunoprecipitation of rat liver arginase using anti-arginase rabbit serum. The silica resin was more effective than the Sepharose in this immunoprecipitation and was easier to separate from solutions. Protein A-silica also was packed into a 4.6 × 30 mm column and used for high pressure affinity chromatography (HPAC). The column was effectively used to isolate IgG from blood serum in less than 15 min. Using homogeneous IgG, peak height was found to be highly linear with sample load over a wide range of concentration. Using such a standard curve, the Protein A-HPAC method should be useful clinically in the analytical determination of serum IgG concentration.

Lyme Disease in Indiana: Isolation of *Borrelia burgdorferi* from Ticks (*Dermacentor variabilis* and *Amblyomma americanum*) and White-footed Mice. Martha M. Ritter and Robert Pinger, Ball State University, Muncie, Indiana 47306.——Lyme disease is a human disease caused by the tick-borne spirochete, *Borrelia burgdorferi*, and is now the most commonly reported tick-borne disease in the U.S. The disease usually begins with a skin lesion (EMC) and may develop to cause cardiovascular complications or acute arthritis. Although the extent of the spirochete's distribution in the midwest is unknown, four clinical cases of the disease possibly originating in Indiana have been reported to the State Board of Health, suggesting the need for more information about the distribution of the spirochete in this region of the country.

Ticks collected from three areas in Indiana and white-footed mice from Crawford, Martin, and Lawrence counties, were examined for the presence of *Borrelia burgdorferi*. Testing procedures included culture of tick midguts and mouse spleen, kidney, and blood samples in BSK-II medium; dark-field exam of direct smears of tissue samples; and direct immunofluorescent tests with rabbit anti-*B. burgdorferi* FITC conjugate.

The Construction of Three Hybrid Cloning Vectors and the Use of Low Iron Medium to Improve Transformation Efficiency in the Cyanobacteria *Anacystis nidulans* R2 and *A. nidulans* R2 SPc. Carolyn N. Vann, Department of Biology, Ball State University, Muncie, Indiana 47306 and Lauren A. Playl and Louis A. Sherman, Division of Biological Sciences, University of Missouri, Columbia, Missouri 65211.——Three hybrid cloning vectors have been constructed which are capable of transforming at a high frequency both *Escherichia coli* and *Anacystis nidulans* strains R2 and SPc. The first vector, pPGV5, contains the indigenous plasmid of *A. nidulans* ligated to an *E. coli* plasmid, pLC28, which carries the powerful leftward promoter of phage lambda. The second vector, pROAN1 is similar but has the leftward and rightward promoters of lambda in addition to sequences encoding the temperature-sensitive CI 857 repressor protein. The third vector contains multiple cloning sites, the T7 and SP6 promoters, the bacteriophage F1 origin of replication, and allows for positive selection of inserts cloned into it. An *A. nidulans* gene encoding a 36 kDa protein involved in iron metabolism was cloned into pPGV5 and transformed into *A. nidulans* R2-SPc. The gene is expressed under control of the lambda promoter when the cells are grown in low iron medium. Transformation efficiency of *A. nidulans* strains R2 and R2-SPc may be improved as much as tenfold by the use of iron deficient medium.

The Use of Aniline as an Indicator of Persistence in Environmental Studies

RICHARD M. KLINE AND CHRISTOPHER A. SCHMALZ
Lilly Research Laboratories
Greenfield, Indiana 46140

Introduction

Biodegradability is suggested by many regulatory agencies as one of the tests to evaluate environmental persistence. The Environmental Protection Agency (EPA) lists several methods in their Chemical Fate Guidelines (3) and similar tests are recommended by the Organization for Economic Cooperation Development (OECD) in their OECD Guidelines for Testing of Chemicals (5).

Aniline is one of the control compounds proposed as a standard for biodegradability in sewage, water, and soil systems. It was suggested because of its aromatic structure which is common to several pesticides.

According to the EPA Guidelines (3), the positive controls must show a removal of 70% of the dissolved oxidizable carbon in the test system within 28 days or 60% of the theoretical carbon dioxide must be produced. A 14-day acclimation period is recommended for these tests. Numerous other investigators also used acclimated inocula in their experiments. Most of these investigators used pure cultures and were interested in metabolic pathways of aromatic compound degradation. Baumgarten, et. al. (2) studied a strain of *Alcaligenes faecalis* which used aniline as the sole source of carbon and nitrogen. A *Moraxella* sp., also capable of mineralizing aniline using it both as a source of carbon and nitrogen, was studied by Zeyer et. al. (8).

Experiments reported here were designed to determine the feasibility of using non-acclimated sewage organisms as an indicator of relative persistence within a group of experimental pesticides.

Materials and Methods

Sewage inocula were obtained from an aerated lagoon of an industrial sewage disposal plant. The plant was constructed to specifications of a municipal waste treatment facility and handles an average of 500,000 to 600,000 gallons of sanitary waste per day. A quantity of sewage was removed, allowed to settle, and filtered through glass wool to obtain a clear, amber liquid. The filtrate was sparged overnight with laboratory air, then fortified with 10 ml/L of synthetic sewage (7). The composition of the synthetic sewage solution is shown in Table 1. Twenty ml quantities of the fortified sewage filtrate were then distributed into 50 ml erlenmeyer flasks.

TABLE 1. Synthetic Sewage

Ingredient	Quantity (g)
Glucose	13.0
Nutrient broth	13.0
Beef extract	13.0
Dipotassium hydrogen phosphate	13.0
Ammonium sulfate	2.5
Tap water	1000 ml

An aniline (Aldrich Chemical Co., Inc., 99% pure) solution was prepared in acetone at a concentration of 1 mg/ml and added to the flasks prior to adding sewage. The acetone was allowed to evaporate and the aniline remained as a film on the glass surface.

One-half of the flasks were aerated on a gyratory shaker at 250 rpm and the remaining flasks were allowed to stand in the laboratory undisturbed. Incubation was accomplished at ambient temperature, approximately 25 °C.

At each sampling interval, representative flasks were removed and 20 ml high-performance liquid chromatographic (HPLC) grade methanol was added to inhibit growth. Flasks were then stored in the freezer, −5 °C, until the experiment was terminated. Before analyses were performed, the contents of each flask and rinses were transferred to 50 ml volumetric flasks. Final volumes were achieved with a methanol water solution (1:1).

At the time of assay, a 5 ml aliquot was removed with a syringe and the contents filtered through a 0.45 micron Acrodisc (Gelman sciences, Ann Arbor, MI). Analyses were performed on an HPLC system composed of a Waters Associates chromatographic pump and a Waters μBondapak C-18 column, 250 × 4.5 mm ID connected to a Model 450 variable wavelength detector set at 235 mm. Volumes of 50 μL were injected and peak heights were measured on chromatograms produced on a Houston Instrument Omniscribe Recorder.

Dissolved oxygen utilization experiments were performed in standard 60 ml biochemical oxygen demand (BOD) bottles. Air saturated dilution water was prepared according to Standard Methods for the Examination of Water and Wastewater (4). Aniline and inoculum were added to bottles as previously described and dilution water was siphoned to volume.

Positive controls containing glucose and glutamic acid, 3 ppm each, were tested with and without aniline to demonstrate toxicity to waste treatment organisms. Inoculum controls, dilution water controls, and aniline controls were also analyzed with each test.

Dissolved oxygen concentrations were determined with a Wheaton 60 Second BOD System. To eliminate contamination, it was necessary to prepare several replicates of each treatment and make only one reading per bottle.

Results and Discussion

Aniline, sodium citrate, dextrose, phthalic acid, and trimellitic acid are proposed as reference compounds for environmental experiments by the Office of Toxic Substances (3). The object is to check the activity of the inoculum to determine unrelated toxicity in test systems. Aniline was selected in these tests because the aromatic structure is basic to several pesticides. It was anticipated that the compound may also be used to predict relative persistence of experimental pesticides under field conditions.

In four different experiments run during the spring season, inocula were taken from the aerated lagoon of the sewage disposal system and fortified with aniline at 10 ppm. Between 5 and 8 days were required to show complete loss of the compound. These data appear in Table 2. Both the mechanically aerated flasks and the non-agitated systems produced similar results, indicating that air was not limiting in the non-agitated flasks

TABLE 2. Effect of Inoculum on Aniline Degradation

Experiment	Degradation[1] Time (Days)	
	Aerated	Non-Aerated
I	—	6
II	7	7[2]
III	8	8[3]
IV	7	7

[1] Aniline concentration below the .156 ppm limit of detection

[2] Did not run 6-day samples

[3] Did not run 7-day samples

and excessive aeration was not inhibitory to sewage organisms. Differences in experiments were anticipated because Jones and Alexander (1985) reported that kinetics were altered by uncharacterized organic substrates, but perhaps the rapid decline observed in these tests made the tests insensitive to the expected environmental changes. When the time intervals were reduced to daily samples, the gradual decrease in aniline content can be seen. As shown in Table 3, the data confirm previous experiments that both methods produced similar results. Large standard deviations at the lower values were the result of one or two replicates with no detectable aniline.

TABLE 3. Effect of Aeration on Aniline Degradation by Sewage Microorganisms

	Aniline Concentration (ppm)			
Time (days)	Aerated	S.D.	Non-Aerated	S.D.
0	8.3	1.0	8.9	1.0
3	7.3	0.1	8.0	0.4
4	5.9	1.7	8.0	0.4
5	2.8	3.0	7.0	0.8
6	0.1	0.2	2.8	2.8
7	0	—	0	—

In two experiments, aniline degradation was followed in a restricted oxygen environment. Aniline concentrations ranged from 1.25 to 10 μg per ml in the two studies, which extended for one month. As previously noted, the mineral salts medium was saturated with air to a concentration approximating 9.0 ppm and measured at several intervals during the test duration.

Each of the aniline-treated systems utilized dissolved oxygen at a rate dependent upon initial chemical concentration. Anson and MacKinnon (1) also found that adapted microorganisms degraded aniline under aerations at a rate dependent upon initial concentration. The two experiments were run with different inoculum concentrations, but the higher the aniline concentration, the more oxygen was utilized. These data appear in Tables 4 and 5. When aniline was analyzed in the high level experiment, it was noted

TABLE 4. Effect of Aniline on Dissolved Oxygen Utilization

		Dissolved Oxygen Concentration (ppm)			
Identity	Day 0	Day 5	Day 15	Day 20	Day 30
Inoculum Control[1]	9.1	7.8	7.5	5.0	6.3
Aniline (10 μg/ml)	9.0	7.1	0.3	0.2	0.4
Aniline (5 μg/ml)	9.1	7.5	1.2	0.3	0.4
Aniline (10 μg/ml) Cont.	9.2	7.7	0.6	0.4	0.4

[1] 1.0 ml inoculum in 30 ml medium

TABLE 5. Effect of Aniline on Dissolved Oxygen Utilization

		Dissolved Oxygen Concentration (ppm)			
Identity	Day 0	Day 5	Day 15	Day 20	Day 29
Inoculum Control[1]	9.2	8.1	6.7	8.2	5.9
Aniline (1.25 μg/ml)	9.4	7.2	5.3	6.7	5.1
Aniline (2.5 μg/ml)	9.3	5.4	4.3	4.4	4.3
Aniline (2.5 μg/ml) Cont.	9.3	7.2	4.9	5.9	5.5

[1] 0.5 ml inoculum in 30 ml medium

that the low concentrations, 5 μg/ml was depleted in 15-20 days (Table 6). However, there were very small quantities of dissolved oxygen remaining after 30 days. This would suggest that in this study, there was insufficient oxygen to completely degrade 10 ppm aniline in the closed container.

TABLE 6. Aniline Degradation Under Limited Oxygen

	Aniline Concentration (ppm)				
Identity	Day 0	Day 5	Day 15	Day 20	Day 30
Inoculum Control	0	0	0	0	0
Aniline (10 μg/ml)	10.8	9.8	3.8	2.2	3.6
Aniline (5 μg/ml)	5.6	4.1	0.4	0	0
Aniline (10 μg/ml) Cont.	11	10.1	2.7	2.4	3.3

Graphic representation of the effect of concentration of aniline on oxygen consumption is shown in Figure 1. As the concentration of aniline was increased, more dissolved oxygen was utilized. Only 36% of the original oxygen content was present after 8 days when the medium contained 5 ppm aniline. At 0.75 ppm aniline, 72% of the dissolved oxygen was present at the same time interval.

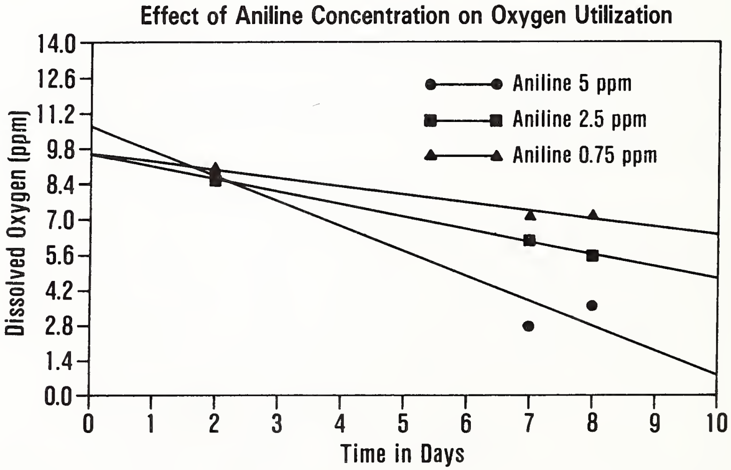


FIGURE 1.

It was also noted in these experiments that the aniline controls, i.e. uninoculated systems, were also showing a loss of oxygen and aniline indicating chemical or physical oxidation, contaminated compound or other system components. To eliminate the possibility that the degradation of aniline was not biological, an experiment was run with sterile controls and aniline content determined at weekly intervals. As shown in Table 7, only one-third of the compound was lost in the sterile flask during a 25-day incubation period. The non-sterile aniline solution showed complete depletion of aniline within one week. To confirm the sterility, a sample of the sterile medium was subcultured into brain heart infusion broth with no apparent growth appearing through 23 days. These data would indicate that the loss of aniline was predominantly associated with biological systems.

TABLE 7. Stability of Aniline Following Sterilization

	Aniline Concentration (μg/ml)				
Identity	Day 0	Day 6	Day 9	Day 16	Day 25
Sterile Cont.	0	0	0	0	0
Sterile Aniline[1,2]	9.0	8.4	6.2	7.6	6.1
Non-Sterile Cont.	0	0	0	0	0
Non-Sterile Aniline[1]	11.0	0	0	0	0

[1] Fortified @ 10 μg/ml

[2] Sterility test - BHI - No apparent growth after 23 days

The addition of glucose-glutamic acid to the sewage increased the rate of oxygen utilization, but the addition of the relatively small quantity of aniline did not alter the rate as shown in Figure 2. Aniline analyses indicated 79% of the original concentration was present after 30 days. Thus, the oxygen consumption was almost entirely attributed to the more easily utilizable glucose-glutamic acid substrate.

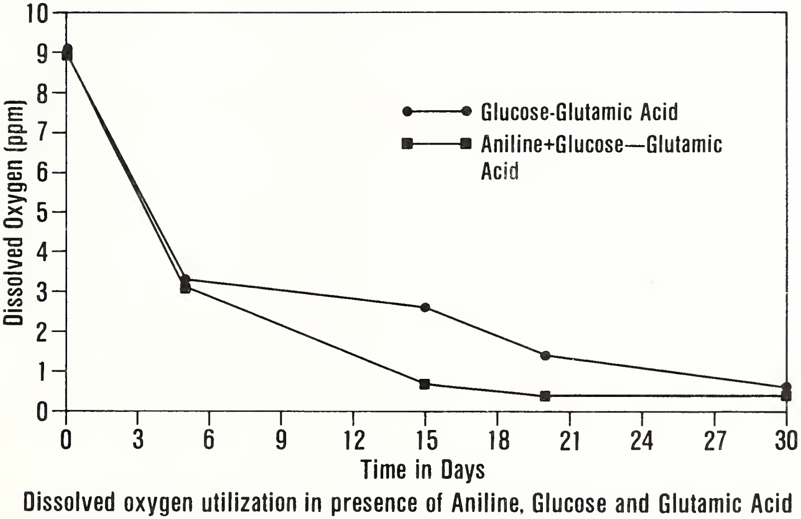


FIGURE 2.

Conclusion

Aniline was shown to rapidly degrade in sewage without an acclimation period. The test compound was added at concentrations equal to or less than 10 ppm which would approximate the concentration of pesticides used on agronomic cropland. The compound as suggested by the OECD (5) and the EPA (3) would appear to be a good indicator of environmental degradation in soil. The rapid degradation of aniline in our test systems prevents its use as a comparative reference to measure the relative persistence of slowly degrading pesticides.

Acknowledgments

The authors wish to thank Mr. J. Peloso and Ms. Theresa Wagner for their assistance in preparation of this manuscript.

Literature Cited

1. Anson, J.G. and G. MacKinnon. 1984. Novel *Pseudomonas* plasmid involved in aniline degradation. *App. Environ. Microbiol.* 48:868-869.
2. Baumgarten, J., T. Mann, and F. Schmidt. 1983. Microorganism cultures decomposing polysubstituted aromatic hydrocarbons and their use in biological sewage plants. Fed. Rep. Ger. Patent 322588J. C.A. 100(14) 108668W.
3. Environmental Protection Agency. 1982. Chemical fate guidelines. Office of Pesticides and Toxic Substances. U.S.E.P.A. Washington, D.C.
4. Greenberg, A.E., R.R. Trussell and L.S. Clesceri. 1985. Standard methods for the examination of water and wastewater. Amer. Public Health Assoc. Washington, D.C.
5. Jones, S.H. and M. Alexander. 1985. Kinetics of phenol and p-nitrophenol mineralization at low concentrations in lake water. Abstracts of the annual meeting of the American Society for Microbiology.
6. Organization for Economic Cooperation and Development. 1982. Guidelines for testing chemicals. O.E.C.D. Publ. Office. Paris.
7. Soap and Detergent Association. 1966. Test procedures and standards. Scientific and technical report No. 3.
8. Zeyer, J., A. Wasserfallen and K.N. Timmin. 1985. Microbial mineralization of ring substituted anilines through an ortho-cleavage pathway. Appl. Envirion. Microbiol. 50:447-453.

Modification of Pyridine Nucleotide Pools in Hela Cells Grown under Growth Promoting Factors

I.L. Sun, P. Navas, D.J. Morré and F.L. Crane
Department of Biological Sciences
Purdue University
West Lafayette, Indiana 47907

Introduction

Numerous studies have shown that pyridine nucleotide levels change in proliferating tissues in comparison to that of non-proliferating tissues (3,4,6,7,10,16,21). The ratio of NAD: NADH also increases as 3T3 cells grow from logarithmic to stationary phase (22). Furthermore, pyridine nucleotide pools have been studied as a function of growth in normal 3T3 cells and SV40 (simian virus #40) transformed 3T3 cells (14). Recently, we have also demonstrated that the reduction of pyridine nucleotide levels in rat liver follows carcinogen (2-acetylaminofluorene) administration (26). Based on these results, it is reasonable to postulate that pyridine nucleotide pools are important in the control of cell division.

In order to see a close correlation between cell replication and the modification of pyridine nucleotide pools, exogenous stimuli for cell proliferation are applied. Fetal calf serum has been the most common supplement used to stimulate growth. Transferrin, a component of serum, has been shown to replace serum in the growth of many cells (13). Similarly, insulin, another component of serum, has been known as an essential growth factor for some cells (1,2). Recently, stimulation of cell growth by impermeable oxidizing agents such as ferricyanide has also been reported (9,17,24,25). Furthermore, evidence for an additive effect on the growth of HeLa cells by insulin and the impermeable oxidant has been demonstrated (27). The application of these exogenous stimuli, which greatly promote cell proliferation in a serum-depleted media, has therefore been performed in order to study the changes in pyridine nucleotide levels.

The regulation and endogenous biosynthesis of pyridine nucleotides is potentially complex since several alternative pathways have been described in mammalian cells (15). Although the significance of the relationship between pyridine nucleotide levels and cell replication is not clear, the possible involvement of pyridine nucleotides in growth control is of great interest.

Materials and Methods

HeLa cells were grown in serum-free Eagle's medium supplemented with growth factors as described previously (25,27). After 2 days of incubation at 37 °C, cells were harvested and a cell survival count was taken immediately. Survival was determined by the eosin Y exclusion method as described by Mishell and Shrigi (19); cell countes were obtained in duplicate after trypsinization. The colorless, viable cells were counted.

The pyridine nucleotide pool was determined by extraction of NAD and NADH from cells with perchloric acid and alkali respectively (14). The extracted pyridine nucleotides were then quantitated by using a cycling assay which involved alcohol dehydrogenase and glucose-6-phosphate dehydrogenase (18).

Results

Pyridine nucleotide pools have been determined in HeLa cells after 48 hour growth in a serum-free medium supplemented with ferricyanide. The optimal concentration of ferricyanide for growth stimulation is 0.01 mM (Figure 1). Total nucleotide pools follow a similar response, with an optimal concentration of ferricyanide at 0.033 mM. As growth

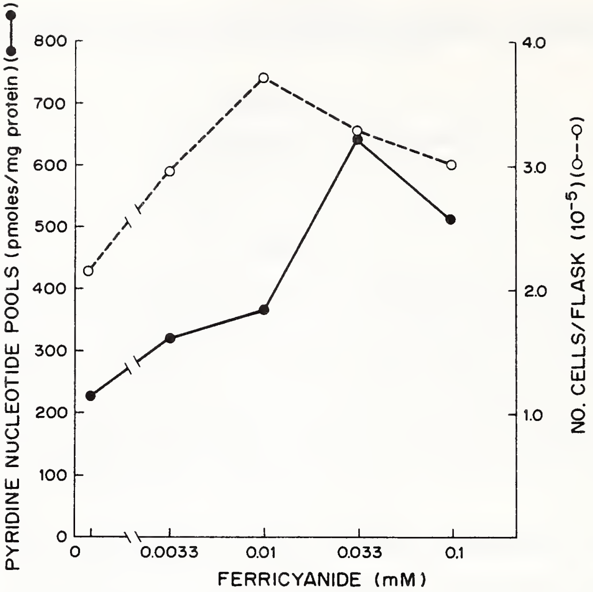


FIGURE 1. Dose-response curve for ferricyanide on cell growth and the induction of pyridine nucleotide pools. The culture of HeLa cells was grown in a serum-free medium for 48 h.

ceases at confluency, pyridine nucleotide levels decline. This correlation between growth and pyridine nucleotides exists for both the reduced form (NADH) and oxidized form (NAD) (Figure 2). When cells are grown with ferricyanide (0.033 mM), NAD concentra-

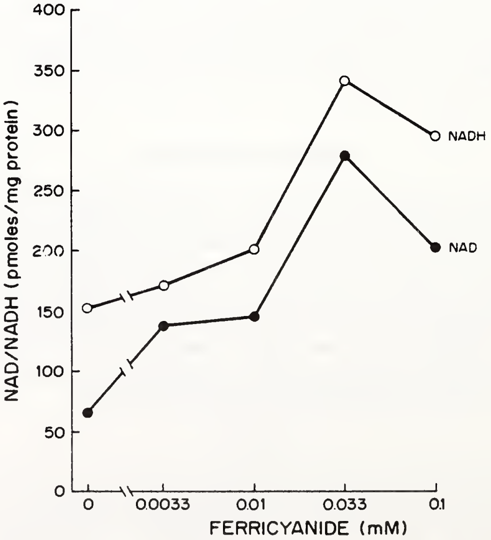


FIGURE 2. Effect of ferricyanide on the pools of NAD and NADH.

tion increases nearly 5-fold over the control, whereas NADH increases 2-fold over the control. Under this growth condition, the levels of the reduced pyridine nucleotide NADH are higher than the oxidized form, NAD.

If the determinatin of pyridine nucleotides pools is performed with HeLa cells grown in serum depleted but insulin-supplemented media, there is a sharp induction of pyridine nucleotide pools as shown in Figure 3, until insulin reaches 3 μg/ml. A downward trend of the pools has been observed when the growth stages shift from logarithmic phase to stationary phase. Each type of pyridine nucleotide is induced in a similar pattern (Figure 4). Again the level of NADH is higher than NAD all the way through the experiment. At the maximum growth, both NAD and NADH are induced to a similar extent.

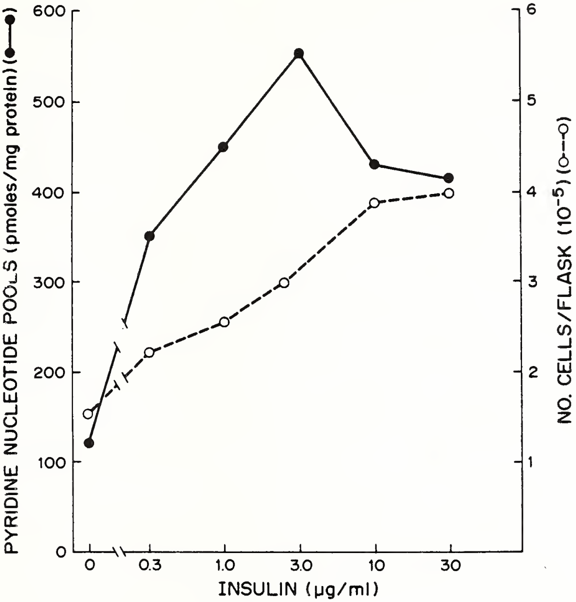


FIGURE 3. Dose-response curve for insulin on the induction of pyridine nucleotide pools and cell growth. Culture was grown in the same way as indicated in Figure 1 except insulin was used as a supplement instead of ferricyanide.

An additive effect of ferricyanide and insulin on the increase of pyridine nucleotide pools is observed when both agents are applied together (Figure 5). Insulin and ferricyanide also show an additive effect on growth of HeLa cells (27).

Evidence for a relationship between pyridine nucleotide levels and growth in HeLa cells is also seen with the application of diferric transferrin (DFTF). DFTF is a well known growth stimulating agent. As shown in Figure 6, DFTF increases cell growth more than 3 fold above the control at a concentration of 3.4 μM, whereas apotransferrin gives insignificant effects on cell growth. Similar effects have been found on total pyridine nucleotide pools (Figure 7). DFTF induces a 2-fold increase but apotransferrin shows no effect. The effect of DFTF and apotransferrin on the concentration of NAD and NADH is shown in Table 1.

To stimulate cell replication, serum has been used as a supplement in the media. The increase in cell numbers is proportional to the concentration of serum applied (Figure

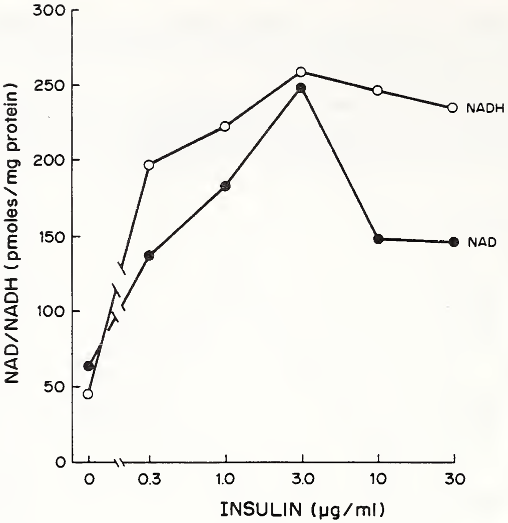


FIGURE 4. Effect of insulin on NAD and NADH pools.

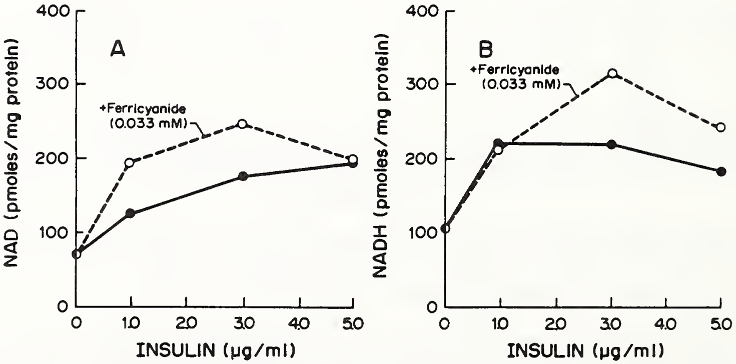


FIGURE 5. An additive effect on the induction of NAD and NADH pools by insulin and ferricyanide.

8). A progressive increase in pyridine nucleotide levels with increasing serum is also demonstrated (Figure 8). Both NAD and NADH increase with added serum (Figure 9).

Discussion

Insulin and transferrin are the major serum factors known to stimulate cell growth (13). However, the stimulation of cell growth by ferricyanide has also been reported by Ellem and Key (14) and from this laboratory (16,18). This electron acceptor can support sufficient electron transport to stimulate cell growth even in the absence of serum factors or serum. It also induces proton release across the membrane (8) which would therefore increase the pH of the cytoplasm. An increase of cytoplasmic pH (alkalinization) is associated with increased cell division (11,12,20).

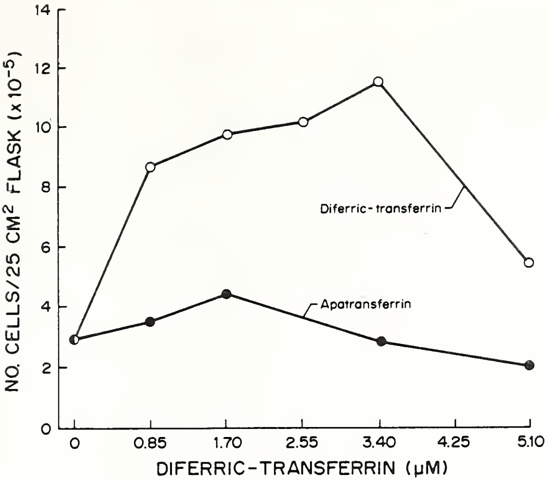


FIGURE 6. Dose-response cuve for diferric-transferrin and apotransferrin on the growth of HeLa cells.

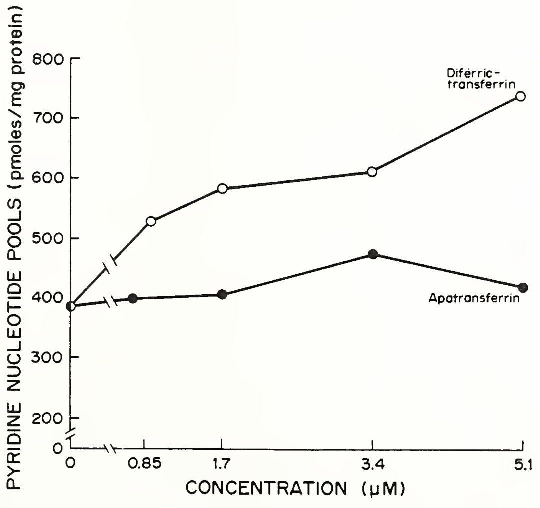


FIGURE 7. Effect of diferric-transferrin and apotransferrin on pyridine nucleotide pools.

TABLE 1. Effect of diferrictransferrin and apotransferrin on the distribution of pyridine nucleotide levels.

Addition	NAD	NADH
	(pmoles/mg protein)	
Control	132.5	65.4
Diferric transferrin (0.85 μM)	170.0	174.8
Diferric transferrin (1.7 μM)	190.0	243.4
Apotransferrin (0.85 μM)	138.6	87.9
Apotransferrin (1.7 μM)	129.8	89.1

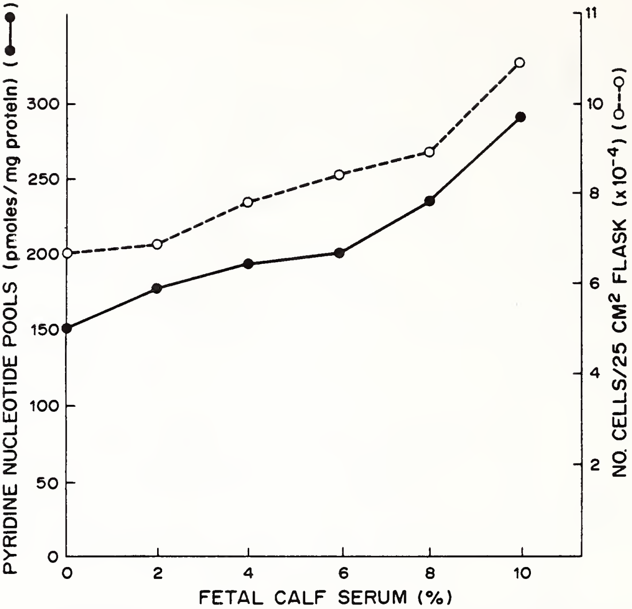


FIGURE 8. Dose-response curve for fetal calf serum on the growth of HeLa cells and the inductin of pyridine nucleotide pools.

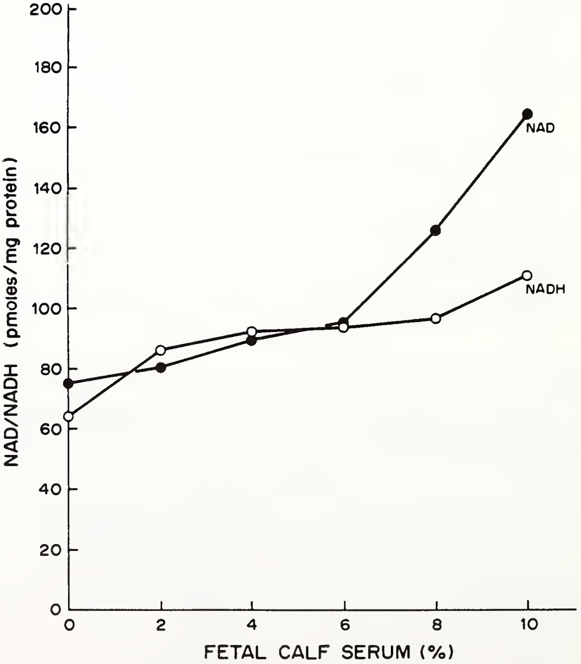


FIGURE 9. Induction of NAD and NADH pools by fetal calf serum.

The effect of growth conditions on NADH pool size and the ratio of oxidized to reduced pyridine nucleotide (NAD:NADH ratio) have been studied in normal and transformed 3T3 cells (22). A decrease in the NAD:NADH ratio was found in transformed cells and the decrease was suggested to relate to the defective growth control in these cells.

Results presented here show that under various growth promoting agents, levels of both NAD and NADH are increased in HeLa cells.

NAD can serve as a substrate in the formation of poly ADP-ribose (poly ADP-Rib), a compound synthesized in mammalian cell nuclei (23). Recent evidence suggests that the accumulation of poly (ADP-Rib) may be involved in turning off DNA synthesis (5.28). The rise in the NADH: NAD ratio which we have observed in this study may therefore regulate DNA synthesis by providing a decrease supply of NAD for poly (ADP-Rib) synthesis. Therefore, cells maintain a continuous synthesis of DNA and growth.

The pyridine nucleotides are important components of the energy-transforming and oxidation-reduction reactions of the cells. The pyridine nucleotide pools can therefore be an indicator of the metabolic capabilities of the cell which varies corresponding to growth conditions. In this paper, an attempt has been made to study the correlation between this indicator and cell replication under the influence of growth promoting agents.

Literature Cited

1. Bottenstein, T., Hayashi, T. Hutchings, S., Masui, H., Mather, T., McClure, D., Ohasa, S., Rizzino, A., Sato, G., Servero, G., Wolfe, R. and Wu, R. (1978) Methods Enzymol. 58, 94-95.
2. Breitman, T.R., Collins, S.J. and Keene, B.R. (1980) Exp. Cell Res. 126, 494-498.
3. Briggs, M.H. (1960) Nature, 187, 249-250.
4. Burch, H.B. and Von Dippe, P. (1964) J. Biol. Chem. 239, 1898-1899.
5. Burzio, L. and Koide, S.S. (1970) (Biochem. Biophys. Res. Commun. 40, 1013-1020.
6. Caiger, P.R., Morton, K., FIlsell, C.H. and Jarrett I. Ct. (1962) Biochem. J. 85, 351-359.
7. Clark, J.B., Greenhaum, A.L. and McLean, P. (1966) Biochem. J. 98, 546-556.
8. Dormandy, T.L. and Zarday, Z. (1965) J. Physiol. 180, 684-689.
9. Ellem, K.A.O. and Kay, G.F. (1983) Biochem. Biophys. Res. Commun. 112, 183-190.
10. Ferris, G.M. and Clark, J.B. (1972) Biochem. J. 128, 869-877.
11. Frelin, C., Vigne, F. and Lazounski, M. (1983) J. Biol. Chem. 258, 6272-6276.
12. Gerson, D.F., Kiefer, H. and Eufe, W. (1982) Science 216, 1009-1010.
13. Hutchins, S.E. and Sato, G.H. (1978) Proc. Natl. Acad. Sci. US. 75, 901-907.
14. Jacobson, E.L. and Jacobson, M.K. (1976) Arch. Biochem. Biophys. 175, 627-634.
15. Jacobson, E.L., Lange, R.A. and Jacobson, M.K. (1979) J. Cell Physiol. 99, 417-426.
16. Jedeikin, E.L. and Weinhouse, S. (1955) J. Biol. Chem. 213, 271-280.
17. Landschulz, W., Thesleff, I. and Ekblom, P. (1984) J. Cell Biol. 98, 596-601.
18. Matsumara, M. and Miyachi, S. (1980) Methods Enzymol. 69, 465-470.
19. Mishell, B.B. and Shrigi, S.M. (1980) in Selective Methods in Cellular Immunology, W.H. Freeman, San Francisco, p. 17.
20. Moolenaar, W.H., Tsien, R.Y., Van der Saag, P.T. and DeLeat, S.W. (1983) Nature 304, 645-648.
21. Nemeth, A.M. and Dickerman, H. (1960) J. Biol. Chem. 235, 1761-1764.
22. Schwartz, J.P. and Passonneau, J.V. (1974) J. Biol. Chem. 249, 4138-4143.
23. Sugimura, T. (1973) Prog. Nucleic Acid Res. Mol. Biol. 13, 127-151.
24. Sun, J.L., Crane, F.L., Grebing, C. and Löw, H. (1984) J. Bioenerg. Biomemb. 16, 583-595.

25. Sun, J.L., Crane, F.L., Löw, H. and Grebing, C. (1984) Biochem. Biophys. Res. Commun. 125, 649-654.
26. Sun, I., MacKellar, W., Crane, F.L., Barr, R., Elliott, W.L., Varnold, R.L., Heinstein, P.F. and Morré, D.J. (1985) Cancer Res. 45, 157-163.
27. Sun, I.L., Crane, F.L., Grebing C. and Löw, H. (1985) Exp. Cell Res. 156, 528-536.
28. Yamada, M., Nagao, M. Hidaka, T. and Sugimura, T. (1973) Biochem. Biophys. Res. Commun. 54, 1567-1572.

PHYSICS AND ASTRONOMY

Chair: Edward A. Vondrak
Department of Mathematics and Physics
Indiana Central University
Indianapolis, Indiana 46227 (317) 788-3311

Chair-Elect: Richard L. Conklin
Department of Physics
Hanover College
Hanover, Indiana 47243 (812) 866-2151

ABSTRACTS

Fiber Optic System for Sensor Applications and Environmental Control. Torsten Alvager, Angel Anez, David Beach and Cindy Thomas, Indiana State University, Terre Haute, Indiana 47809.——The recent introduction of fiber optical light guides for remote spectroscopic sensing has opened a new era of studies of hostile or otherwise inaccessible environments. The method is also of importance in a variety of other situations such as in studies of solid state systems and systems related to damage and environmental control.

A problem often hampering the possible use of the fiber optical light guide technique is the scattering of light that occurs when low transparent samples are investigated. In this study the general objective has been the development of a method to enhance the fluorescence signal in relation to the scattering signal of a typical measurement with fiber optic remote spectroscopic sensing. This has been achieved by use of a well-known timing method. Preliminary experiments indicate that an enhancement of at least a factor times one hundred is possible to obtain using the new method.

Observing Halley's Comet from Indiana and Brazil. Malcom E. Hults and Roger L. Scott, Ball State University, Muncie, Indiana 47306.——Halley's Comet was not a bright object duirng the 1985-86 apparition, but its appearance was of extreme interest to astronomers and the general public over the world. In the fall and winter months the comet was rather faint and was seen best through binoculars and telescopes. However, during March and April 1986, the comet reached easy naked eye visibility and exhibited a tail several degrees in length. The authors were able to observe the comet several times from December 1985 to May 1986, and to photographically record its changing appearance. Observations were made by both authors in Indiana, and by author Hults in Brazil, South America. Photographs were taken with a number of films; Kodak Professional Ektachrome (ISO 800/1600) yielded the best results. Slides of the comet taken at various distances from the earth will be shown and correlated with the respective positions of the earth and comet in their orbits. The authors also will show a few slides of the beautiful southern constellations and discuss a cooperative program between Ball State University and the Federal University of Santa Maria in Brazil.

Radon Daughter Concentrations in Selected Homes in Indiana, Illinois and Michigan. Elmer N. Nussbaum, Roger W. Roth, Department of Physics, Taylor University, Upland, Indiana 46989 and Jon A. Roth, ITT, Aerospace/Optical Division, Fort Wayne, Indiana 46801.——Radon concentrations of indoor air are inferred from the measured alpha activity of radon daughters collected on a millipore filter that has sampled the air. The total alpha disintegrations during three selected time intervals after the sampling period are determined with a windowless gasflow proportional counter. The initial concentrations of the radon progeny RaA (Polonium-218), RaB (Lead-214), and RaC (Bismuth-214) are then calculated using the method developed by Thomas (Thomas, Jess W., *Health Physics*, Vol. 23, 783, 1972). The results, expressed in working level (WL), ranged from 1 mWL to 18 mWL.

Voice Recognition and Speech Synthesis as Aids in Real-time, Computer-aided Measurements of High Energy Physics Star Events in Nuclear Emulsion. Gerald P. Thomas and Sue Thompson, Ball State University, Muncie, Indiana 47306.——A description is given of the operation and use of an Interstate Electronics SYS 300 Voice Recognition System and Votrax Personal Speech System in the optimization of a real-time, computer-aided Koristka optical-microscope-based 3-d measurement technique in the field of experimental high energy physics. This optimization reduces the need for movement by the microscopist thereby reducing the difficulty and duration as well as the measurement error of these inherently delicate measurements.

Fast-neutron-Activation Analyses of Various Water Sources of East Central Indiana

Diana S. Bennett
Matthew J. Buchkowski
Cheryl A. Bye
David L. Loewenstein
and
David R. Ober
Department of Physics and Astronomy
Ball State University
Muncie, Indiana 47306

Introduction

In recent years, much attention has been focused on the extent of environmental contamination. This problem has grown extensively primarily due to expansions in the industrial sector. Therefore, an adequate means for the detection and monitoring of potential industrial contamination was needed. In response the following methods of analysis have been used successfully for detection of environmental contamination: 1) gas chromatography (organic contents); 2) coulometric titration (dissolved gases); 3) electrochemical techniques (inorganic anions); 4) atomic absorption spectrophotometry (metals); and 5) neutron activation analysis (metals) (1). This study utilized fast neutron activation analysis (NAA) in an effort to determine the trace element composition of various northeastern Indiana water supplies. The source of neutrons for this study was the Ball State University Neutron Generator. This facility has been used previously in studies that searched for trace elements in coal, aspirin, precipitation (snow), and water samples.

The primary purpose of this investigation was to document regional fluctuations in the concentrations of certain trace elements found in the water samples. The study included local sampling sites representing both river and drinking water supplies. At three of the drinking water sites, multiple samples were taken at different times in an effort to study the time dependence of trace elements and to check the reproducibility of results.

Theoretical Considerations

Neutron activation analysis (NAA) takes advantage of the fact that characteristic radioactive isotopes are produced when a sample containing trace elements is bombarded with fast neutrons. The resulting unstable isotopes subsequently decay either by gamma-ray or beta emission. By measuring the gamma-ray emissions with a high resolution Ge detector/multichannel analyzer system, gamma-ray energies and half lives may be determined. This enables one to determine the parent isotope associated with a particular gamma ray, thus providing a means for identifying the trace element present in the original sample (target).

The fast neutrons for this investigation were produced by a Cockcroft-Walton type neutron generator by accelerating dueterium ions through a potential difference of 150 kV and allowing them to strike a stationary tritium target, inducing the following nuclear reaction:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He^{++} + ^{1}_{0}n + 17.6 \text{ MeV}.$$

The neutrons in this reaction have a kinetic energy of 14 MeV with the rest of the energy (3.6 MeV) being carried away by the alpha particle.

The initial disintegration rate A_0 (activity) of the product nuclei is directly proportional to the number (N) of target nuclei present in the sample, the neutron flux (ϕ) in n/(cm^2/s), the reaction cross section (σ), and a time-dependent exponential saturation term which is dependent upon the decay constant (λ) and the time of irradiation (t_r):

$$A_o = N\phi\sigma(1 - e^{-\lambda t}r).$$

From this relation it can be seen that activity is directly propotional to the neutron flux. Because the sensitivity of the procedure depends on the activity of the sample, higher fluxes produce greater sensitivities. The flux effect can be visualized by comparing the flux and sensitivities of both fast and thermal neutrons. The thermalized neutron fluxes available in reactors are on the order of 10^{12} - 10^{13} (n/cm^{2}s). The fluxes of fast neutrons from sources such as that used in this investigation are three to four orders of magnitude less (10^9 n/(cm^{2}s) (2). The sensitivities obtained by this method are typically 0.5 ppm, whereas the sensitivities resulting from thermalized neutrons have been reported for selected elements to be on the order of 1 ppb. For example, sensitivities of 0.4 ppb gold, 0.6 ppb cobalt, 3 ppb copper, and 6 ppb zinc are not uncommon (1).

The sensitivities of this investigation were computed by comparing unknown samples with known amounts of standard solutions, taking into account relative flux and time corrections before comparison of the activities.

Experimental Details

The fast (14-MeV) neutrons used in this investigation were produced by the Ball State Neutron Generator facilities which include a 150-kV Cockcroft-Walton accelerator and a borontrifluoride (BF_3) neutron flux monitor system.

The gamma-ray spectrometer system consisted of a high resolution intrinsic germanium (Ge) detector (12.5% efficiency), a multi-channel analyzer, and a printer/plotter. The detector resolution was approximately 2.5 keV full width at half maximum (FWHM) at 1332 keV (^{60}Co).

The following steps were carried out in obtaining and preparing samples for irradiation: 1) sample site selected, 2) sample collected, 3) sample concentrated, and 4) sample transferred to a suitable medium for irradiation.

The drinking water sites were selected primarily on the basis of convenience, since they were the drinking water supplies of three of the investigators. The sites were in rural areas adjacent to Muncie — Jay County (northeastern), Union City, and Yorktown. The other sample was taken from the Muncie city water supply. Also chosen for study was the principal source of Muncie's drinking water, the White River. The latter was sampled in three different locations: 1) east of the city at the intake of the Water Treatment Plant, 2) middle of the city near Indiana Steel and Wire, and 3) west of the city near the Sewage Treatment Plant. This selection of sites was designed to detect changes in water composition as a function of location along the river. By choosing these various sites, it was hoped that a comparative water quality study could be obtained.

Soon after collection, the samples were subjected to a rigorous concentration procedure, consisting of evaporation of the water to obtain a more concentrated sample of smaller size. Twenty liters were collected and placed in either 1000-mL or 2000-mL beakers and allowed to boil down until approximately 50-mL was left. During this process precipitates formed. To speed the transfer of the remaining sample to smaller containers, concentrated nitric acid was added to dissolve the precipitates (if soluble). Nitric acid was chosen over other acids, such as hydrochloric and sulfuric, primarily because it does not activate.

To calculate trace element concentrations, it was necessary to prepare and irradiate standard solutions of known concentrations. Such solutions were made for all of the major elements that had been identified or were expected to be found in the water supplies.

Five-minute irradiation times were used. The samples were taped directly onto the end of the accelerator and exposed to a neutron flux for five-minutes. After an irradiation was completed, the activated sample was taken to the Ge detector and placed directly on top, at which time data acquisition was begun. The delay time (typically 60 to 110 seconds) was taken into consideration for computing concentrations. Generally, gamma-ray spectra of the water samples were recorded in five-minute intervals and composite spectra were obtained also for ten-, twenty-, and forty-minute intervals. The standard samples were counted in five-minute intervals for fifteen minutes. Ten-minute composite spectra were obtained also.

Results

A. Analysis of Sample Spectra

The photopeak energies were determined using internal calibration standards such as K-40, T1-208, and the 511-keV annihilation energy. By comparison of the gamma-ray energies and half lives of the sample and standard spectra, the water-sample photopeaks were identified as to the target element responsible for the associated gamma rays (Figure 1). The concentrations of the detected elements were calculated by using the previously determined empirical sensitivities and normalizing them for flux and delay time associated with each spectrum.

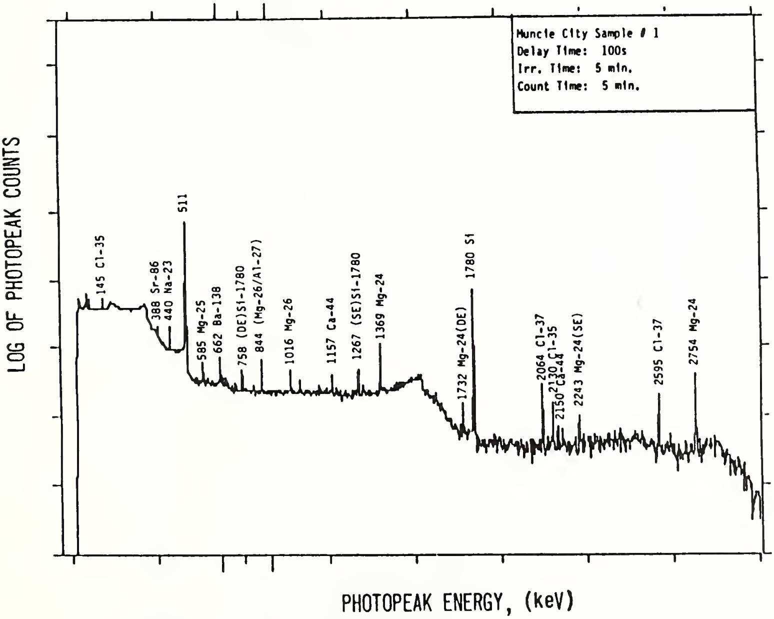


Figure 1. A gamma-ray spectrum acquired after a 5-min irradiation of a 20-L concentrated Muncie city drinking water sample. Identified peaks are associated with the trace elements that were activated by the 14-MeV neutrons; gamma-ray energies are expressed in keV.

B. Drinking Water Supplies

Using these methods, nine elements were found to be present in the various drinking water supplies (Table 1). Calcium, chlorine, magnesium, potassium, sodium, and

Table 1. Results of the concentration levels of trace elements detected in the drinking water samples; concentration levels are expressed in parts per million (ppm).

Element	Jay Co. Well # 1	Jay Co. Well # 2	Jay Co. Well # 3	Muncie City # 1	Muncie City #2	Muncie City # 3	Yorktown Well # 1	Yorktown Well # 2	Yorktown Well # 3	Union City # 1
Aluminum	.06 ppm	.05 ppm	.04 ppm	.88 ppm	.88 ppm	.45 ppm	.36 ppm	.38 ppm	.40 ppm	.29 ppm
Barium	.04 ppm	.03 ppm	.03 ppm	.15 ppm	.27 ppm	.17 ppm	.24 ppm	.23 ppm	.20 ppm	.40 ppm
Calcium	77 ppm	82 ppm	55 ppm	146 ppm	154 ppm	150 ppm	88 ppm	106 ppm	101 ppm	89 ppm
Chlorine	—	—	—	15 ppm	45 ppm	43 ppm	37 ppm	31 ppm	22 ppm	6.7 ppm
Iron	1.1 ppm	1.8 ppm	1.5 ppm	3.0 ppm	3.6 ppm	1.5 ppm	1.0 ppm	1.5 ppm	1.1 ppm	1.8 ppm
Magnesium	56 ppm	57 ppm	55 ppm	27 ppm	27 ppm	24 ppm	37 ppm	36 ppm	36 ppm	23 ppm
Potassium	2.4 ppm	2.6 ppm	2.7 ppm	5.3 ppm	4.9 ppm	4.9 ppm	2.7 ppm	2.6 ppm	2.5 ppm	.4 ppm
Sodium	47 ppm	40 ppm	32 ppm	13 ppm	22 pm	17 ppm	15 ppm	16 ppm	20 ppm	16 ppm
Strontium	18 ppm	20 ppm	16 ppm	3.9 ppm	4.1 ppm	5.5 ppm	1.6 ppm	1.0 ppm	.95 ppm	5.6 ppm

strontium were found in gross amounts, whereas, aluminum, barium, and iron were found in trace quantities. The concentrations of the detected elements were independent of sampling time except for the following: the aluminum, potassium, and chlorine concenrations of the Muncie City water supply. Since chlorine, alum, and potassium permanganate are some of the common substances added for water purification, fluctuations in these concentrations were expected (3). The iron concentrations were found to be approximately 1.0 ppm, which is a normal background level for this area based upon an atomic absorption study performed on these same samples (4).

Regional differences in several trace element concentrations were observed among the various drinking water samples. The Delaware County area has a larger barium concentration than the Jay County area. Barium is commonly found in water supplies in the form of carbonates and sulfates. Due to the insoluble nature of these salts, it is normally found in trace amounts, under the 1.0 ppm standard for safe drinking water (5). The aluminum concentrations seemed to follow the same trend as the barium. Because aluminum is one of the most abundant elements found in nature, its presence in the water supplies was not unexpected. One of the more interesting regional differences in trace element concentrations can be found in the strontium concentration levels (Table 1); the Jay Conty samples have significantly more strontium than those from Delaware County. Strontium is normally found in nature as a slightly soluble sulfate salt; however, its presence in such high levels was unexpected (5). It can also be seen that the city water supplies were lower in magnesium content than were the county well sites. For a more complete graphical presentation of concentration results (Figures 2 and 3).

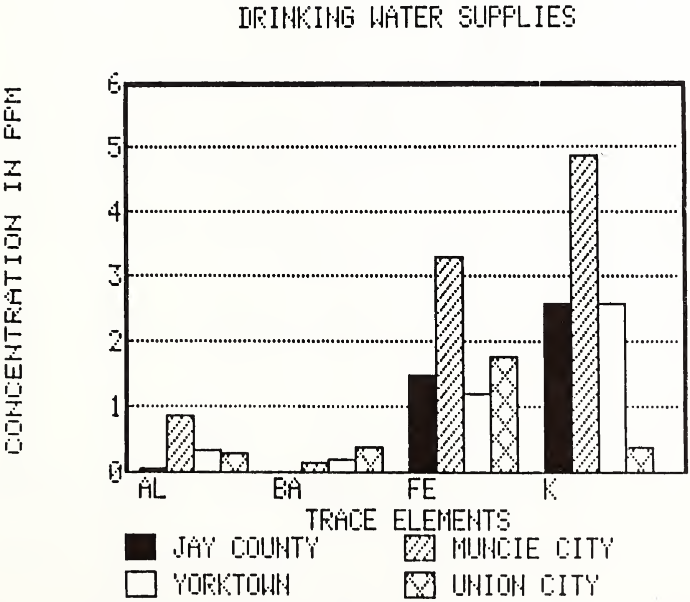


FIGURE 2. A graphical comparison of the concentration levels for aluminum, barium, iron, and potassium in parts per million (ppm), for the drinking water samples.

C. River Water Supplies

Nine elements were also identified in the river water samples (Table 2). However,

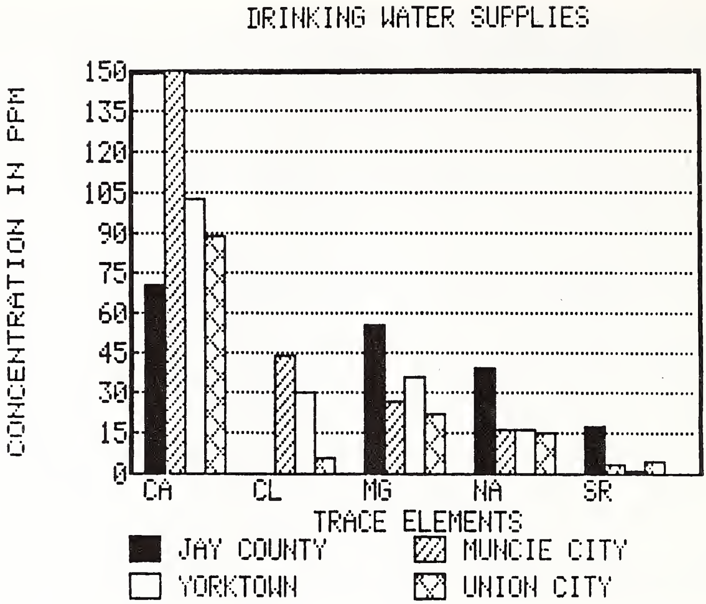


FIGURE 3. A graphical comparison of the concentration levels by sample for calcium, chlorine, magnesium, sodium, and strontium in parts per million (ppm).

TABLE 2. Results of the concentration levels of trace elements detected at three sampling sites along the White River at Muncie, Indiana; sampling sites were chosen where the river entered the city (Water Treatment Plant), a site within the city (near Indiana Steel and Wire), and a site beyond the city (Sewage Treatment Plant). Sample concentrations are expressed for elements detected in ionic and particulate (filtered) form. Concentration levels are expressed in parts per million (ppm).

Element	Water Treatment Plant Intake	Water Treatment Plant (Filter)	Indiana Steel And Wire	Indiana Steel & Wire (Filter)	Sewage Treatment Plant	Sewage Treatment (Filter)
Aluminum	.41 ppm	5.0 ppm	.81 ppm	5.1 ppm	.91 ppm	5.8 ppm
Barium	.04 ppm	.15 ppm	.08 ppm	.09 ppm	.12 ppm	.12 ppm
Calcium	43 ppm	45 ppm	48 ppm	35 ppm	65 ppm	34 ppm
Chlorine	5.8 ppm	—	3.2 ppm	—	20 ppm	—
Iron	.21 ppm	.71 ppm	—	4.1 ppm	.98 ppm	3.0 ppm
Magnesium	20 ppm	7.7 ppm	22 ppm	8.0 ppm	34 ppm	—
Potassium	2.7 ppm	2.6 ppm	2.9 ppm	2.4 ppm	4.3 ppm	1.69 ppm
Sodium	20 ppm	—	26 ppm	—	31 ppm	—
Strontium	.33 ppm	1.07 ppm	.48 ppm	.56 ppm	.75 ppm	1.6 ppm

as one would expect, these elements were detected in much higher concentrations than for the drinking water samples. Concentrations were seen to vary as a function of location along the river. The farthest upstream site was the water treatment plant, the next was the river near Indiana Steel and Wire, and the last sample was taken approximately one mile downstream from the sewage treatment plant. In most instances, the concentrations increased as one moved farther downstream. Alum, an aluminum salt, and potassium permanganate were being added as purifiers to the river water at the water treatment plant. This could account for the higher levels of aluminum and potassium observed further downstream. Figures 4 and 5 are graphical representations of concentration levels at various sites along the White River.

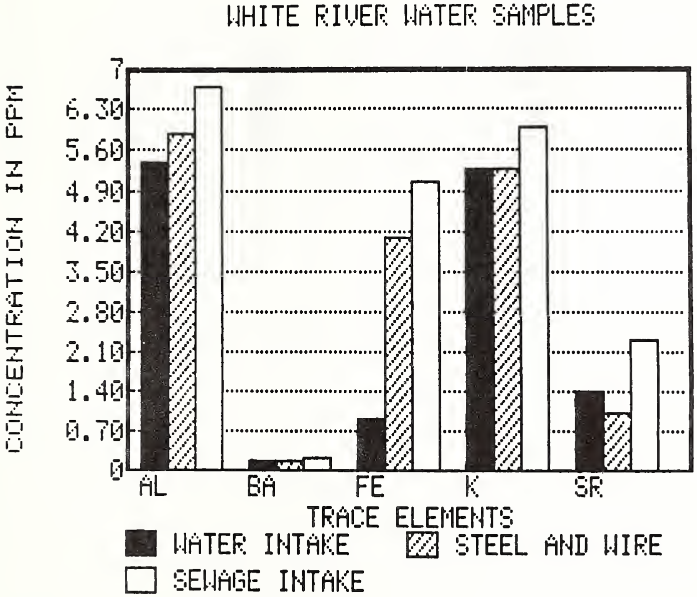


FIGURE 4. A graphical comparison of the concentration levels of aluminum, barium, iron, potassium, and strontium in parts per million (ppm) for three sampling sites along the White River at Muncie, Indiana.

D. *Comparisons and Contrasts*

The water samples in this investigation were found to have trace-element concentration levels similar to those of comparable sites. As one would expect, the river sample concentration levels were typically higher than those of the drinking water supplies.

Perhaps the most interesting comparison can be made between the Muncie City water samples and the White River samples. Both supplies showed similar levels of barium, iron, magnesium, potassium, and strontium, which was expected, since the White River is the source of Muncie's water (Tables 1 and 2).

Conclusions

The methods of fast neutron activation analysis (NAA) proved to be successful in identifying and determining the concentrations of nine elements commonly found in water

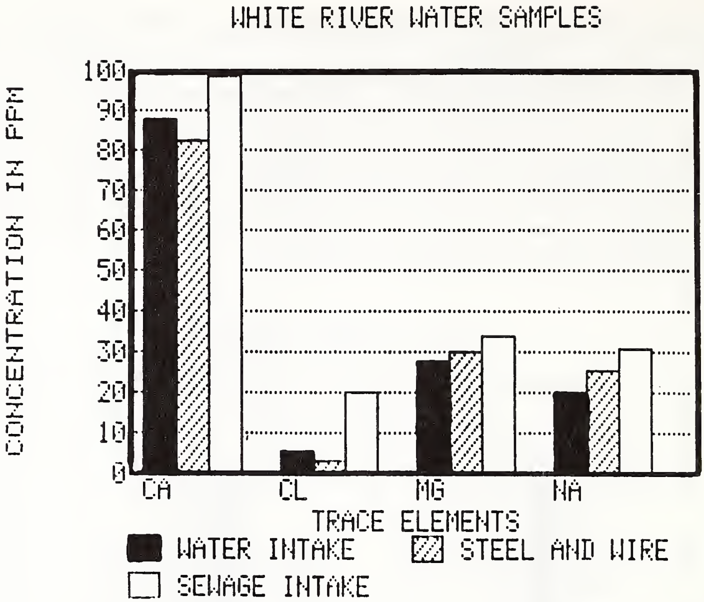


FIGURE 5. A graphical comparison of the concentration levels of calcium, chlorine, magnesium, and sodium, in parts per million (ppm) for three sampling sites along the White River at Muncie, Indiana.

supplies. The following elements were identified both qualitatively and quantitatively by this method: aluminum, barium, calcium, chlorine, iron, magnesium, potassium, sodium, and strontium. Silicon was also detected but only qualitative comparisons were done since silicon is found in all water samples. For the most part, calcium, magnesium, potassium, and sodium were found in gross amounts, whereas, aluminum, barium, iron, and strontium were found in trace quantities. It was estimated that the overall sensitivity of NAA was in the ppm range; this estimate was substantiated by the fact that results by the NAA were in excellent agreement with atomic absorption spectroscopy measurements to within specified uncertainties (4).

The strontium levels in the Jay County samples were considerably higher than the levels found in other similar water supplies. This could imply that there are strontium deposits located in the Jay County area. It was also noted that the aluminum concentrations for Muncie's drinking water were higher than normal; however, the addition of alum (aluminum sulfate) is quite common when drinking water is taken from a river supply. Overall the trace element concentration levels were consistent among samples and independent of sampling time. All of the concentrations for drinking water samples were within the USPHS Drinking Water Standards (3).

Literature Cited

1. *Instrumental Analysis For Water Pollution Control*, Ed. by Khalil H. Mancy, Ann Arbor Science Pub., Inc., Ann Arbor, Michigan, 1971.
2. Abuzeid Y. Ahmed, "High Resolution Gamma-ray Spectra Of Some Common Elements Irradiated With 14-MeV Neutrons," M.S. Thesis, Ball State University, 1973.

3. *Handbook Of Environmental Control Volume III: Water Supply And Treatment*, Ed. by Richard G. Bond, Conrad P. Straub, Ph.D., and Richard Prober, Ph.D., CRC Press, Cleveland, Ohio 1973.
4. "Atomic Spectroscopic and Neutron Activation Analyses of Trace Heavy Metals in Water Supplies Surrounding a Municipal Landfill," Cherly A. Bye and James P. Rybarczyk, Ph.D., Ball State University, Muncie, Indiana, 1986. (Unpublished.)
5. J.F. Kopp and R.C. Korner, "A Five Year Summary of Trace Metals in Rivers and Lakes of the United States (October 1, 1962 - September 30, 1967)", and references therein, United States Department of the Interior (FWPCA), Cincinnati, Ohio.

An Investigation of the April 1986 Chernobyl Radioactivity Releases as Detected in Muncie, Indiana

William W. Wong
Cheryl A. Bye
and
David R. Ober
Department of Physics and Astronomy
Ball State University
Muncie, Indiana 47306

Introduction

On Apil 26, 1986, a severe accident at the Soviet Union's Chernobyl Unit 4 Nuclear Power Station caused an intense fire that lasted several days, melted large quantities of reactor fuel, and released into the environment a large fraction of the reactor's inventory of volatile radioactive fission products. Observers in Poland and Scandinavia were the first to trace the radioactive fallout to a source in the Soviet Union. The fallout cloud was expected to reach the United States within several weeks, so it was decided to carry out a study of the local fallout at Muncie, Indiana, following the Chernobyl accident.

Two objectives were established for this study: (1) to identify the fission products from the fallout and (2) to determine the concentrations of the fission products above the local background. Furthermore, it was hoped that comparisons could be made with concentration levels in Muncie with those in other parts of the United States and the world.

Experimental Details

A. Air Sampling Procedure

A high volume air sampler (General Metal Works model 2000 H) was used to collect the fallout debris on an asbestos-like filter paper. The fine mesh filter paper, approximately 8 × 10 in, was sufficient to capture particulate matter with sizes greater than or approximately equal to 0.3 micron. The air sampler was placed in a small enclosure at the Ball State University weather station on the Ball State campus and allowed to operate for 24 hours. During this time a volume of approximately 2000-2200 cubic meters was drawn through the filter.

After removal from the air sampler, the filters were folded and gamma-ray spectra were recorded for a 20-hour period with the high-resolution germanium detector in a standard face-to-face geometry. The detector and filter were enclosed by four inches of lead shielding to minimize the room background radiation.

The sample-acquisition and -counting procedures were repeated for approximately two months (May and June), with samples being obtained about three times a week.

A second set of five filters was obtained from the Indiana State Board of Health. These filters had been obtained from a Muncie sampling station (on top of Muncie Central High School) operated by the state. The filters were taken at six-day intervals from May 2 through May 26. Each filter had about 1800 cubic meters of air drawn through it and its radioactivity contents were determined in the same manner as the Ball State Weather Station filters.

B. Spectrometer System

FIlter activities were determined by observing gamma rays associated with the fission decay products. The gamma-ray spectrometer system included the following: a high voltage power supply, 12.5% efficient germanium detector, preamplifier, linear amplifier, and a Nuclear Data (model ND 62) 4096-channel multichannel analyzer.

The germanium detector was chosen for its superior energy resolution (2.5-keV full-width maximum at 1332 keV for Co-60). Its high resolution (compared to NaI detectors) and large peak-to-Compton ratios enabled one to identify the presence of weak gamma-ray yields and confirm their associated energies with a much smaller number of total photopeak counts than would be required with a NaI detector.

The gamma-ray energies and intensities of the photopeaks were recorded for each sample. The radioisotopes present in the samples were then identified by their known gamma-ray energies and half-lives. Comparisons were made with compilations of standard spectra as found in the Nuclear Data Tables.

C. Room Background

The natural background radiation in the room was also detected while counting the sample filters. Even though lead shielding surrounded the germanium detector, the background plus sample spectra were dominated by the room background radiation.

Present in the room background spectrum are gamma rays from the decay of K-40 present in the soil and concrete surrounding the laboratory. Most of the room background came from T1-208, Pb-214, and Bi-214, the daughter products associated with the isotopes of radon (Rn-222) and thoron (Rn-220).

D. Germanium Detector Photopeak Efficiency

To make absolute activity determinations it was necessary to determine the germanium detector's photopeak efficiency. Calibrated standards, including Na-22, Cs-137, and Radium, from the National Bureau of Standards were used for this purpose. A photopeak efficiency curve as a function of gamma-ray energy was then obtained for the detector. Interpolations of efficiencies from this graph were used to assign the absolute activities quoted in this investigation.

Experimental Details

A. Air Filter Spectra

Shown in Figure 1 is the gamma-ray spectrum associated with an air filter sample drawn for 24 hours on May 13, 1986 at the Ball State Weather Station. The gamma-ray spectrum is for a 20-hour count period.

Photopeaks were identified for the following isotopes attributed to the Chernobyl releases: Ru-103, I-131, Cs-134, and Cs-137. Photopeak energies associated with these isotopes are 497 keV, 364 keV, 796 keV, and 662 keV, respectively. Photopeaks that have not been labeled are associated with the nautral room background; the 1460.7-keV and 2614.5-keV photopeaks of K-40 and T1-208, respectively, are identified to assist in relative intensity and energy observations.

B. Radiation Associated with Chernobyl

Presented in Figure 2 and Table 1 are the graphical and tabulated results of detected radiation related to the Chernobyl releases. Each day's results were obtained by analyzing the gamma-ray spectrum associated with the 24-hour filter drawn on that day. In Figure 2 it should be noted that the log of activity is plotted along the y-axis as a function of time.

From the graph it can be seen that most of the radioactive fallout arrived at Ball State University on May 13, 1986, two weeks after the accident. It was for this reason that the second set of filters was obtained from the State Board of Health; these filters bracketed this period of high activity and their results are presented in Table 2.

Clearly the I-131 is characteristic of the Chernobyl accident, but it is also evident that the other isotopes detected in this investigation (Ru-103, Cs-134, and Cs-137) reached maximum activity level (20 times above normal background) at the same time as did

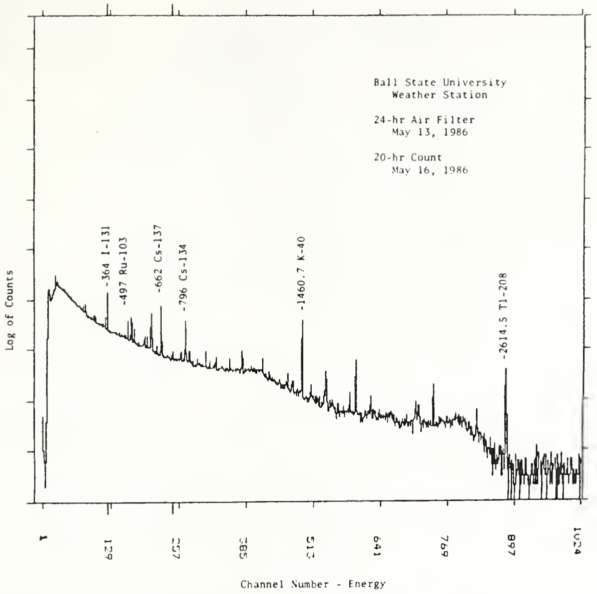


FIGURE 1. A gamma-ray spectrum acquired from a 20-hr count of the filtered particulat air sample taken at the Ball State Weather Station; identified activities are labeled by th parent nuclide and energies are expressed in keV. The isotopes associated with the Che nobyl releases are Ru-103, I-131, Cs-134, and Cs-137.

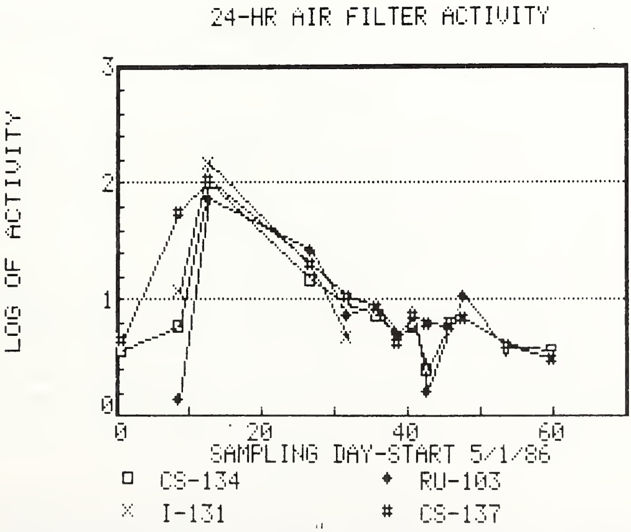


FIGURE 2. Daily activities of the Chernobyl related fallout in Muncie (Ball State Weat Station) from May 1 to June 29, 1986. Presented in Table 1 is the numerical data sho in this figure.

TABLE 1. Ball State University 24-hr Air Filter

Filter	Date	Ru-103	I-131	Cs-134	Cs-137
		Measured Activities (pico Curies)/2200 m³			
May	1	—	—	3.1 ± 1.3	4.6 ± 1.0
	9	1.4 ± 1.3	12 ± 1.7	5.0 ± 1.5	56 ± 1.3
	13	76 ± 2	148 ± 2	89 ± 2	111 ± 2
	27	27 ± 1.4	20 ± 1.4	13 ± 1.2	21 ± 1.1
June	1	7.5 ± 1.1	4.9 ± 1.4	7.8 ± 1.4	11 ± 1.2
	5	9.3 ± 1.1	—	6.4 ± 1.3	8.8 ± 1.1
	8	5.1 ± 1.0	—	4.2 ± 1.3	4.3 ± 1.1
	10	7.7 ± 1.2	—	5.1 ± 1.4	7.5 ± 1.1
	12	1.7 ± 1.2	—	2.2 ± 1.4	6.2 ± 1.3
	15	5.9 ± 1.4	—	5.6 ± 1.5	5.9 ± 1.3
	17	11 ± 1.1	—	5.9 ± 1.1	7.0 ± 1.1
	23	2.8 ± 1.0	—	3.6 ± 1.1	4.2 ± 0.7
	29	—	—	3.3 ± 1.2	3.1 ± 0.9

TABLE 2. Muncie Central (State Board of Health) 24-hr Air Filter

Filter	Date	Ru-103	I-131*	Cs-134	Cs-137
		Measured Activities (pico Curies)/1872 m³			
May	2	8.0 ± 2.8	—	0.4 ± 0.4	0.6 ± 0.4
	8	2.5 ± 1.5	—	1.6 ± 0.6	1.4 ± 0.4
	14	200 ± 5	—	41 ± 1	72 ± 1
	20	8.3 ± 2.0	—	6.5 ± 0.6	11.0 ± 0.6
	26	14.5 ± 2.4	—	6.4 ± 0.6	10.4 ± 0.6

* The air filters were counted for activity 89-108 days after the samples were drawn; therefore, the 8-day I-131 activity was not detected at that time.

the I-131 activity. It should be noted that these three additional isotopes are characteristic of a reactor discharge.

Discussion

The current investigation demonstrated that valuable air-quality information can be obtained from gamma-ray measurements on radioactive samples collected on high volume air filters. It also was found that one wave of radioactivity from Chernobyl passed over Ball State University on May 13; data taken several months later from filters taken at a second sampling site in Muncie showed similar results.

Information obtained from the Indiana State Board of Health for radioactivity levels associated with the Chernobyl accident and detected in other states, showed that the Chernobyl radioactivity levels were greater for the western states of the United States (of order 1 pCi/cubic meter and less) than observed in this study for Muncie. The radioactivity levels deposited on the eastern states of the United States seemed to be less than that found in this investigation. The isotopes detected in this study (I-131, Ru-103, Cs-134, and Cs-137) were basically the same as those observed in other parts of the United States.

Acknowledgments

The authors would like to thank the Radiological Health Staff of the Indiana State Board of Health for sharing five of their air filters for analysis in this investigation. The data shared by this group relating to Chernobyl activities measured by them and others throughout the United States is also gratefully acknowledged.

PLANT TAXONOMY

Chair: John W. McCain
Department of Plant Pathology
University of Minnesota
St. Paul, Minnesota 55108

Chair-Elect: Clifton Keller
Director of Academic Computing
Andrews University
Berrien Springs, Michigan 49102 (616) 471-3129

ABSTRACTS

Two Decades of Change in the Tree Stratum of Hoot Woods, Owen County, Indiana. D. Brian Abrell, Division of Nature Preserves, Indiana Department of Natural Resources, Indianapolis, Indiana 46204 and Marion T. Jackson, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.——All trees ($\geq$ 10 Cm dbh) were measured and mapped in 1966 in a 6.6 hectare southern portion of Hoot Woods, a 25 hectare mature upland forest dominated by American beech and sugar maple. In August 1979 extensive light gaps were created by tornadic winds which produced three major storm tracts across the sample area, plus several other isolated tree falls. Mapped trees were re-measured in 1986 to determine changes in forest composition due to the usual growth and replacement of individual trees during 20 years, plus comparisons between full canopy areas and light gaps resulting from recent wind damage.

Leatherleaf Bogs of Indiana. James R. Aldrich and Lee A. Casebere, Indiana Department of Natural Resources, Indianapolis, Indiana 46204.——The occurrence of leatherleaf bogs in Indiana is limited to the Northwestern Morainal and Northern Lakes Natural Regions. Several sites were field checked to determine their natural quality and those that were found to be relatively undisturbed were further studied. Many of the species that occur in leatherleaf bogs such as *Andromeda glaucophylla*, *Xyris caroliniana*, *Calla palustris*, *Vaccinium oxycoccos* and *Scheuchzeria palustris* var. *americana* are rare or otherwise noteworthy species for the Indiana flora. The vegetation and ecology of this wetland type is discussed and a species list presented.

New Artificial Hybrids in *Helianthus*. Charles Heiser, Indiana University, Bloomington, Indiana 47405.——In an attempt to learn more about evolution in *Helianthus* and to develop material for improving the domesticated sunflower, several new artificial hybrids have been produced. (1) *H. hirsutus* (4n) × *H. decapetalus* (2n). This hybrid proved to be tetraploid. (2,3) *H. grosseserratus* (2n) × *H. tuberosus* (6n) and *H. tuberosus* (6n) × *H. divaricatus* (2n). Both of these hybrids proved to be pentaploid. The ploidy level of the above three hybrids can be explained if an unreduced gamete of the diploid parent was involved. (4) A hybrid of *H. tuberosus* (6n) × *H. grosseserratus* (2n) was tetraploid as expected. The hybrid showed 34_{II}, $32_{II}\ 1_{IV}$, and $30_{II}\ 2_{IV}$. (5) *H. annuus* (2n) × *H. hirsutus* (4n). The two hybrids of this combination were doubled with colchicine to produce hexaploids. Some multivalents and univalents were observed at diakinesis. (6) Several triploid hybrids between perennial diploid and tetraploid species were obtained but so far attempts at doubling these with colchicine have been unsuccessful. The significance of these results is to be discussed.

Within Tree Leaf Variability and Evidence for a Developmental Difference Between Pin Oak and Black Oak. RICHARD J. JENSEN, Saint Mary's College, Notre Dame, Indiana 46556.——Leaf morphology was analyzed for within and between tree differences in pin oaks (*Quercus palustris*) and black oaks (*Q. velutina*) in northern Indiana. Four-way factorial ANOVA was used to assess positional and seasonal variation in quantitative features, including counts, angles, linear measurements, and areal measurements. While each tree revealed a different pattern of effects, a general observation is that counts and angles are less variable than linear and areal measurements. The use of a transformation to correct for size demonstrated that some seasonal differences reflect simple change in overall size while others reflect differential rates of change in the measured traits. Of particular interest is evidence that the two species illustrate a pronounced seasonal difference in petiole growth.

Preliminary Polyacrylamide Gel Electrophoresis (PAGE) Survey of Isozymes in Populations of the Bean Rust Fungus. JOHN W. MCCAIN AND JAMES V. GROTH, Department of Plant Pathology, The University of Minnesota, St. Paul, Minnesota 55108.——Preliminary surveys of mass field collections and single-uredial isolates of *Uromyces appendiculatus* (Pers.) Unger, the causal agent of bean rust, indicate the existence of isozymic polymorphism for several enzymes that are not related to virulence. We are attempting PAGE of isozymes extracted from germinated uredospores. Most enzymes tested so far show up as 1-2 bands on stained disc gels but 6-11 bands have been observed on gels stained for nonspecific esterases or for 6-phosphogluconic acid dehydrogenase. Mass field collections, which are mixtures of phenotypes, are highly polymorphic; isolates show fewer bands. The isolate W73-2 has never been induced to reproduce sexually. As a result, gene recombination is probably less frequent. We are presently investigating how frequent sexual reproduction affects isozyme variation.

Progress toward a Photographic Field Guide to Indiana Wildflowers. KAY MCCRARY YATSKIEVYCH, Herbarium, Department of Biology, Indiana University, Bloomington, Indiana 47405.——Amateur botanists, park naturalists, and others often have difficulty accurately identifying Indiana wildflowers because of inadequacies of currently available field guides (the three most commonly used guides lack 20-35% of Indiana species). Intensive photographic field work during the past two years toward a complete and up-to-date field guide to Indiana wildflowers has resulted in slides of approximately 800 species (excluding trees, grasses, sedges, and rushes) and a like number of pressed voucher specimens. A computerized data base has been assembled from herbarium data and the literature, containing information on ranges, habitats, flowering dates, and characters for field identification of all species reported for the state. Continuing work is addressing such problems as methods of familial separation and recognition of species in problem genera. Individual generic treatments will consist of photographs illustrating the immediate visual impact of major morphological groups, supplemented with line drawings and short descriptive summaries of critical characters that separate each species.

Cryptogams Collected by Thomas G. Lea from Indiana and Ohio, 1836-1842

FAY KENOYER DAILY
Butler University
Indianapolis, Indiana 46220

Introduction

A folder of specimens was received from Dr. Charles Reimer of the Academy of Natural Sciences of Philadelphia. A faded pencilled note on the folder said, "Within are Bryophytes collected by Thomas Lea. However, the majority may be Herb. of unknown collector." Another note on the folder expanded the message to indicate that there were algae and mosses collected in the Cincinnati region and there was the suggestion that Leo Lesquereux had written the names. The algae were all charophytes. There was only one moss, and it was the only specimen indicated as collected by T.G. Lea in the collection data with the material.

A sample of handwriting by Leo Lesquereux was kindly sent by Dr. Francis Hueber of the Smithsonian Institution. It was quite obvious that none of the writing on the packet, mounting sheets or notes accompanying some specimens belonged to Lesquereux. His handwriting had a distinct, neat appearance. The handwriting at hand had a strong right slant, indistinct letters, some noticeable peculiarities, and it was hard to read. Dr. Reimer obtained handwriting samples of T.G. Lea from a notebook of flowering dates at the Library of the Academy of Natural Sciences of Philadelphia. When compared with handwritten identifications and data, it was soon apparent that all of the handwriting was Lea's. This was corroborated by Prof. Ronald Stuckey of Ohio State University who is very familiar with Lea's handwriting, and Mr. John Frederick who verified that none of the writing was that of Leo Lesquereux. Notes with some of the specimens were similar to some found with flowering plants collected by T.G. Lea and mentioned in a publication by Dr. E. Lucy Braun (1). The collecting sites closely corresponded to some mentioned by Dr. Braun, too. Upon reading Lea's notes, it is clear that Dr. John Torrey identified most of the specimens. The identifications were sometimes conveyed to Lea by an associate of Torrey and friend of Lea, Mr. John Carey. Dr. Torrey was uncertain about some of the identifications, so Lea sent the material to E. Doubleday (Kew Gardens, Great Britain). No changes were made in identifications, though. Perhaps an answer did not come before Lea's death. Evidently news was slow in coming judging from a letter (also supplied from the Library of the Academy of Natural Sciences of Philadelphia) from Lea to M.J. Berkeley of Great Britain. Some fungi are mentioned which Lea had sent to Doubleday with the hope that W.J. Hooker would see them. Mr. Lea had not heard from him and in his *Catalogue of Plants* (2) cites Rev. Berkeley as having identified them. W.J. Hooker is credited with authenticating the species of mosses. He may have seen the charophytes, too, but Torrey's identifications were not changed. Dr. Torrey became interested in the algae with the help of Lewis D. Schweinitz and planned to include them in a flora of North America. Unfortunately, it was never finished.

Specimens Seen

All specimens can be found in the Academy of Natural Sciences of Philadelphia. They were collected in the vicinity of Cincinnati, Ohio, by Thomas G. Lea except one collected in Indiana. The identifications by the author and collection data are given in Table 1.

It is interesting that the identification of the moss in Packet 9 was originally *Hypnum gracile* Br. and Sch. [now placed in synonymy with *Thuidium microphyllum* (Sw.) Best published in 1843]. Lea died in 1844, so he must have written the data on the moss

TABLE 1. Identifications and collection data.

Packet	Identification	Col. Date	Habitat
1	*Nitella acuminata* f. *subglomerata* (A. Br.) R.D.W.	Sept. 5, 1837	Toward Ludlow's in small pond near canal bank
2	Same	Sept. 17, 1836	Este's "bog", ditch, north end
3	*Chara contraria* A. Br.	June 12, 1839	Este's "bog", ditch, west side
4	*Nitella acuminata* f. *subglomerata* (A. Br.) R.D.W.	Aug. 12, 1837	Pond near canal bank near Ludlow's
5	*Chara contraria* A. Br.	July, 1842	Este's "bog", ditch west side
6	*Nitella acuminata* A. Br. ex Wallm.	Oct. 12, 1840	Este's "bog", north end in slow water
7	*Chara zeylanica* f. *elegans* (A. Br. ex T.F.A.) H. & J. Gr.	Sept. 14, 1838	Ohio River below Ludlow's near shore
7A, B	*Chara contraria* A. Br.	Sept. 1, 1838	Bog rivulet, Mr. Barnes, Indiana
8	*Chara gymnopitys* A. Br.	Oct. 12, 1840	Este's "bog", upper end near ditch
9	*Thuidium microphyllum* (Sw.) Best	None given	None given

packet during the 1843 to 1844 period. The Cincinnati collection sites can be located on Map 1.

A hand-written copy of Lea's *Catalogue of Plants* was found at the Library of the Academy of Natural Sciences of Philadelphia. At the end of it, some additions were written in pencil as follows:

"Characeae
Nitella nidifica Ag.
Chara vulgaris Linn.
Chara aspera Willd."

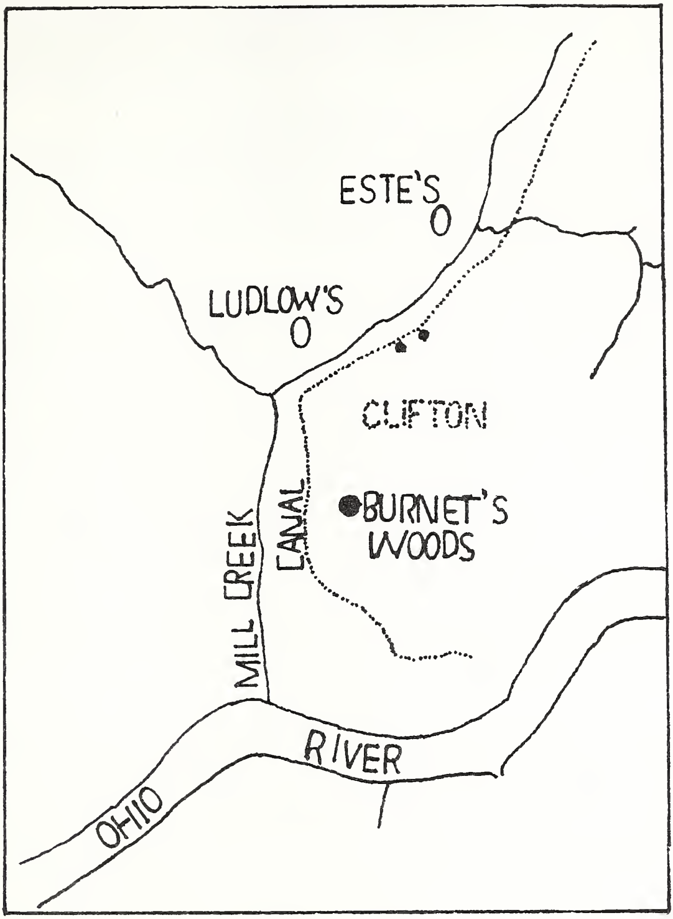
These are the same species names given originally to the specimens of Characeae reported here. Why they do not appear in the printed version published posthumously can only be surmised.

Habitat

In a geological report on Ohio by John L. Riddell (3), the Cincinnati area is classified as the Blue Limestone District. He states, "The composition of the most prevalent soil in the district may be known by studying the nature of the limestone, and of the interlaminar marl or shale for no one who scrutinizes the subject with philosophic care can doubt its having been produced and its being now in progress of production, by the decay or disintegration of those strata - - - - here the surface being generally inclined and the rock either superficial or not far beneath it, as fresh portions of limestone or marl crumble to pieces; they are transported by showers of rain and mingled with the soil down the declivity."

An analysis of the soil by John Locke revealed that from one hundred grains of limestone from the hills of Cincinnati, the following ingredients were yielded; carbonate of lime, 90.93 grains; peroxide of iron, 3.15 grains; matter soluble in muratic acid, 1.80 grains; carbonate of magnesia, 1.11 grains; silex from solution, 0.77 grains; water expelled by red heat, 1.13 grains; loss, 1.11.

Farther on in his report, Dr. Riddell states, "I am indebted to my friend, D. Lapham, Esq. for samples of yellowish marly clay taken from the diluvial deposits of Mill Creek Valley. Its color is brownish yellow and it consists essentially of quartrose aluminous



MAP 1. Orientation of collecting sites in Cincinnati, Ohio (adapted from Braun (1)).

and limestone particles of impalpable fineness.'' It has been used to make very durable brick.

The Cincinnati sites where specimens in this study were collected were located in the Mill Creek Valley near Mill Creek or the canal or near the Ohio River. Dr. E. Lucy Braun (1) in 1934 said that during Lea's time, the area looked like this, ''The bordering hills were wooded or farm land, and the broad valley of Mill Creek, now a factory section for twelve miles of its length, was partly farm, but largely wooded or swamp land.'' Dr. Braun described Este's as, ''the most distant locality in the Mill Creek Valley visited by Lea. It lay opposite the present site of Ivorydale to the northeast of Winton Place. Here the labels indicate a variety of habitats- ponds, ditches, bog, prairie bog, prairie and hill woods. - - - - Este's is on the west side of Mill Creek in a sandy glacial soil area. - - - - The 'bog' may have been a true bog or swamp. In it were *Rhus vernix*, *Dulichium arundinaceum* and *Carex rostrata*, plants of northern range which distinctly indicate the presence here of a boreal, probably bog, relic colony.''

Ludlow's was described by Dr. Braun as on the west side of Mill Creek about two miles below Este's. She mentioned several large springs emerging on the property. Whether these produced the "ponds" mentioned by Lea is not known. Dr. Braun commented after mentioning the springs, "nowhere can we find its counterpart today." The Ohio River site has seen changes with the passing years also.

In summary, the Cincinnati area studied by Lea had changed dramatically by the time Dr. Braun wrote her account of Lea's herbarium. She says, "The rich collecting grounds of 1840 are the factory sites of today. Habitats, briefly described in words, and amply demonstrated by groups of specimens, are utterly destroyed and with them their characteristic flora."

One charophyte came from Indiana. The locality was hard to read on the note accompanying 1C-84 (No. 7A in this study), but Lea's archives helped verify the locality. They contained a letter (at the Library of the Academy of Natural Sciences of Philadelphia) from T.G. Lea to John Carey of New York, February 14, 1839 (letterbook) which mentions a packet of plants sent for identification. Many of the plants were collected in Indiana. Lea received an answer August 9, 1839. The citation, "Carey letter Aug/ 39" occurs on a note accompanying Lea's specimen 1C-84. The note quotes from the letter as follows, "84 looks like *C. vulgaris* but Dr. Torrey was unwilling to give a certain species"

Also from Lea's letterbook in the Lea collection, a loose note mentions the letter from Carey in which no mention was made of numbers 76-80 from Indiana also sent to Torrey. Number 84 is close to this sequence. Credence is accordingly given to the Indiana locality for specimen number 84 although, purportedly, all specimens in the folder were collected in the Cincinnati, Ohio, area.

These letters also substantiate that the specimens reported here were those of T.G. Lea and that John Torrey identified them.

Conclusions

For the few collections of charophytes represented here, there are two genera and four species showing a rich charophyte flora for a small collecting area. The specimens are interesting from the standpoint of their age, the supplemental value they lend to the published work of Lea and the well-known botanists involved. Neither *Hypnum gracile* now transferred to *Thuidium microphyllum* nor any of the charophytes were included in Lea's (2) printed *Catalogue of Plants.*

Acknowledgments

This is a note of appreciation to Dr. Charles Reimer and Ms. Carol M. Spawn of the Academy of Natural Sciences of Philadelphia, also Mr. John Frederick and Prof. Ronald Stuckey of Ohio State University and Dr. Francis Hueber of the Smithsonian Institution for many favors.

Literature Cited

1. Braun, E. Lucy. 1934. The Lea herbarium and the flora of Cincinnati. The American Midl. Nat. XV (1): 1-75.
2. Lea, Thomas G. 1849. Catalogue of plants, native, naturalized collected in the vicinity of Cincinnati, Ohio, during the years 1834-1844. Philadelphia. T.K. and P.G. Collins. 77 p.
3. Riddell, John L. 1837. Report of a special committee to report on the method of obtaining a complete Geological Survey of the state. Ohio Executive Documents No. 60. 30 p.

A Floristic Survey of a Limestone Glade in Versailles State Park, Ripley County, Indiana

Michael A. Homoya
Division of Nature Preserves
Department of Natural Resources
Indianapolis, Indiana 46204

Introduction

A glade is currently defined as a natural opening in the forest caused (in part) by bedrock at or near the surface (14). Glades are normally dry to xeric environments, typically on steep south to west-facing hillsides, and are characterized by a dominance of herbaceous vegetation that often has a scattering of scrubby woody species. In Indiana, they occur on a variety of bedrock types, including limestone (2, 3, 9), sandstone (3), and siltstone (4). Previously, Indiana glades were thought to be restricted to the south-central part of the state, predominantly in the unglaciated portions of the Shawnee Hills and Highland Rim Natural Regions (7). This report apparently provides the first published report of limestone glades in southeastern Indiana, as well as the first for the Switzerland Hills Section of the Bluegrass Natural Region.

Methods

An inspection of aerial photos of Versailles State Park and the immediate surroundings revealed the presence of four glade sites, but only the one on Falling Timber Creek, the largest and most diverse of the four, is discussed here. The glade was visited briefly for an initial ground survey on 10 June 1986, followed by more thorough floristic surveys on 7 August and 7 October. Those taxa in the open part of the glade, as well as in the scattered patches of scrubby woody growth, were recorded. For the most part, the present list represents a visual documentation of taxa in the field; the few vouchers taken are to be deposited in the Deam Herbarium of Indiana University (IND).

The Study Area

The glade is located at Versailles State Park in Ripley County, Indiana, and is part of the Switzerland Hills Section of the Bluegrass Natural Region (7). The glade is situated on a steep south-facing hillside adjacent to a bend of Falling Timber Creek, occupying an area approximately 225 feet in length and 50 feet in height. It is comprised of a sparsely vegetated, rocky slope with large patches of herbaceous vegetation interspersed with stunted trees (primarily *Quercus muhlenbergii*), and shrubs (see Figure 1). The substrate of the glade consists primarily of thin, neutral to alkaline Eden flaggy silty clay loam (10) and Ordovician limestone and shale of the Dillsboro and Whitewater Formations (12).

Results and Discussion

Although there are several reports on vegetation studies conducted at Versailles State Park (8, 11, 13), none indicate the presence of glade communities. As well, there are no known reports of glade communities in any portion of extreme southeastern Indiana. The absence of reports is not surprising, however, given the apparent rarity and small-sized examples of the type. Glades were expected in this region though, considering reports of glade occurrences in the similar Eden shale belt of the Bluegrass region in Kentucky (5).

Little is known concerning the past character of the Falling Timber Creek glade. It doubtless was always small, being restricted to the steep rocky slopes next to the creek. This is inferred from reports of the presettlement land survey (6), that state that the landscape of the park was (in 1806) predominantly forested, with no reference to glades.

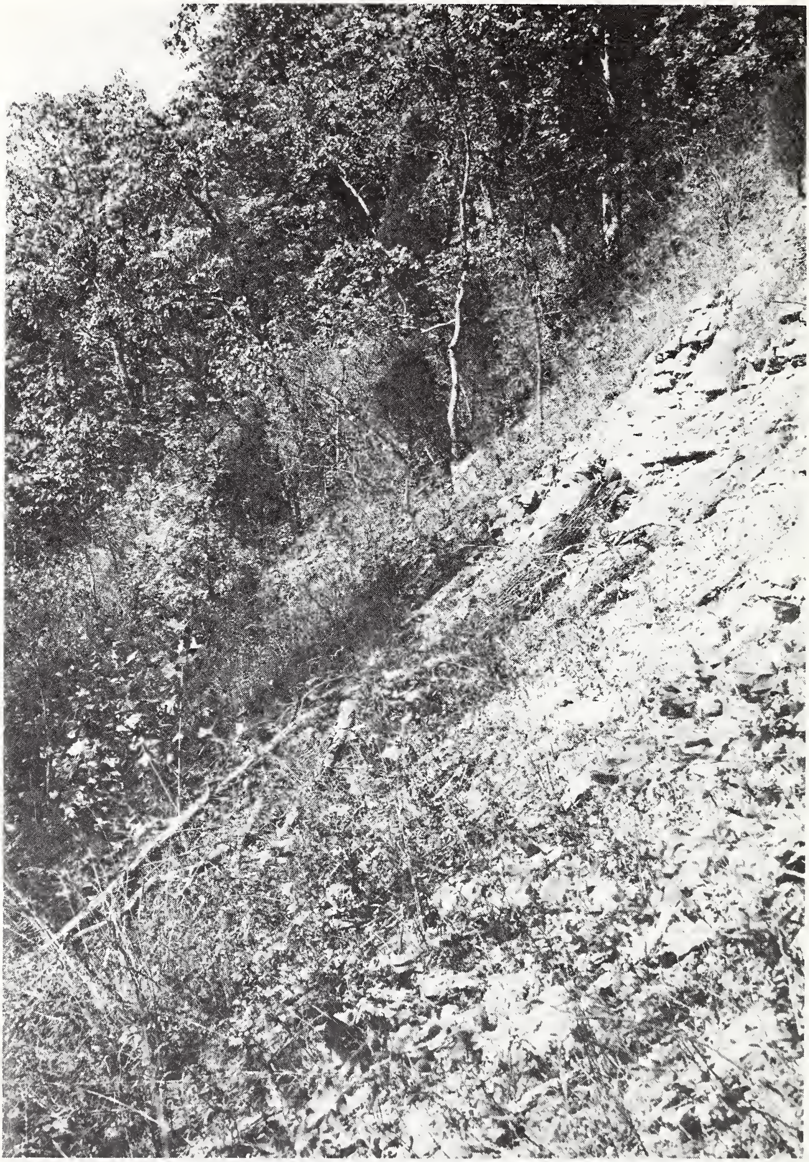


FIGURE 1. Photo of the limestone glade along Falling Timber Creek, Versailles State Park, Indiana.

Natural forest openings that may have been glades were in the area though, for on the west-facing slopes above Laughery Creek (just south of the park) there was, as described by the early land surveyors, a "cedar grove" of several acres in size. Given the aspect and geology of the site, and the presence of cedars (limestone glades are often called cedar glades), it's possible that the "cedar grove" was a limestone glade. The site today is a cattle pasture.

Even with the extensive degree of development in the area of the park since settlement, the glade has apparently avoided major disturbances, as evidenced the relative lack of exotic species (those few present are very rare). Exotics are notorious for displacing indigenous species on heavily disturbed sites. Openings downstream of the glade on hillsides with less steep slopes (where livestock formerly grazed) are dominated by exotics.

Eighty-four taxa were identified as occurring on the glade (Table 1). Of these, *Andropogon gerardii, Aster sagittifolius, Silphium trifoliatum, Physostegia virginiana, Lithospermum canescens*, *Kuhnia eupatoriodes*, *Helianthus hirsutus*, and *Euphorbia corollata* are the herbaceous species with the highest estimated importance values. Important woody species include *Quercus muhlenbergii*, *Viburnum rufidulum*, *Celastris scandens*, *Cercis canadensis*, *Ceanothus americanus*, and *Juniperus virginiana.* Although

Table 1. Vascular Flora of a Limestone Glade in Versailles State Park.

Taxa
Aceraceae
Acer saccharum Marsh.
Anacardiaceae
Rhus glabra L.
Rhus radicans L.
Apocynaceae
Apocynum cannabinum L.
Asclepiadaceae
Asclepius tuberosa L.
Betulaceae
Ostrya virginiana (Mill.) K. Koch
Bignoniaceae
Campsis radicans (L.) Seem.
Boraginaceae
Lithospermum canescens (Michx.) Lehm.
Caprifoliaceae
Viburnum rufidulum Raf.
Celastraceae
Celastrus scandens L.
Euonymus atropurpureus Jacq.
Compositae
Ambrosia artemisiifolia L.
Antennaria plantaginifolia (L.) Hook.
Aster sagittifolius Willd.
Aster undulatus L.
Helianthus hirsutus Raf.
Kuhnia eupatorioides L.
Senecio obovatus Muhl.
Silphium trifoliatum L.
Convolvulaceae
Convolvulus spithameus L.
Ipomoea pandurata (L.) G.F.W. Mey.
Cornaceae
Cornus racemosa Lam.
Cupressaceae
Juniperus virginiana L.
Cyperaceae
Carex sp.
Dioscoreaceae
Dioscorea quaternata (Walt.) Gmel.
Equisetaceae
Equisetum arvense L.

TABLE 1.—Continued

- Euphorbiaceae
  - *Acalypha rhomboidea* Raf.
  - *Euphorbia corollata* L.
- Fagaceae
  - *Quercus alba* L.
  - *Quercus muhlenbergii* Engelm.
  - *Quercus velutina* Lam.
- Gentianaceae
  - *Frasera caroliniensis* Walt.
  - *Gentiana quinquefolia* L.
- Gramineae
  - *Angdropogon gerardii* Vitman
  - *Andropogon scoparius* Michx.
  - *Bromus purgans* L.
  - *Danthonia spicata* (L.) Beauv.
  - *Muhlenbergia* sp.
  - *Panicum dichotomum* L.
  - *Panicum* sp.
  - *Poa compressa* L.
  - *Sorghastrum nutans* (L.) Nash
  - *Sphenopholis intermedia* Rydb.
  - *Sporobolus vaginiflorus* (Torr.) Wood
- Hamamelidaceae
  - *Hamamelis virginiana* L.
- Iridaceae
  - *Sisyrinchium albidum* Raf.
- Labiatae
  - *Monarda fistulosa* L.
  - *Physotegia virginiana* L.
- Leguminosae
  - *Amphicarpa bracteata* (L.) Fern.
  - *Cercis canadensis* L.
  - *Desmodium bracteosum* (Michx.) DC.
  - *Desmodium rotundifolium* DC.
  - *Lespedeza intermedia* (S. Wats.) Britt.
  - *Melilotus alba* Desr.
- Liliaceae
  - *Polygonatum canaliculatum* (Muhl.) Pursh
- Oleaceae
  - *Fraxinus americana* L.
  - *Fraxinus quadrangulata* Michx.
- Oxalidaceae
  - *Oxalis grandis* Small.
  - *Oxalis* sp.
- Passifloraceae
  - *Passiflora lutea* L.
- Platanaceae
  - *Platanus occidentalis* L.
- Polygalaceae
  - *Polygala senega* L.
- Polypodiaceae
  - *Asplenium platyneuron* (L.) Oakes
- Primulaceae
  - *Dodecatheon media* L.
- Ranunculaceae
  - *Anemone virginiana* L.
  - *Clematis viorna* L.
- Rhamnaceae
  - *Ceanothus americanus* L.

TABLE 1.—Continued

Rosaceae
Amelanchier arborea (Michx. f.) Fern.
Fragaria virginiana Duchesne
Potentilla simplex Michx.
Rosa carolina L.
Rosa multiflora Thunb.
Rosa setigera Michx.
Rubus occidentalis L.
Rubus sp.
Rubiaceae
Galium circaezans Michx.
Santalaceae
Comandra umbellata (L.) Nutt.
Saxifragaceae
Hydrangea arborescens L.
Solanaceae
Physalis sp.
Ulmaceae
Ulmus rubra Muhl.
Umbelliferae
Thaspium barbinode (Michx.) Nutt.
Thaspium trifoliatum (L.) Gray
Violaceae
Viola sororia Willd.
Vitaceae
Parthenocissus quinquefolia (L.) Planch.

the glade lacks the glade endemic species such as are found on the limestone glades in south-central Indiana, e.g. *Hypericum dolabriforme*, *Viola egglestonii*, and *Leavenworthia uniflora*, the glade nevertheless supports several species that are quite local in southeastern Indiana, namely *Andropogon gerardii*, *Ceanothus americanus*, *Lithospermum canescens*, *Kuhnia eupatorioides*, *Convolvulus spithamaeus*, *Physostegia virginiana*, *Sorghastrum nutans*, and *Sisyrinchium albidum*. One species, *Aster undulatus*, is listed on the state list of rare, threatened, and endangered species (1). In the other glades in the park and immediate area, other locally rare species occur, e.g. *Bouteloua curtipendula* (Michx.) Torr., *Liatris aspera* Michx., and *Gentiana alba* Muhl. (= *G. flavida* Gray).

Additional field work will likely reveal the occurrence of other glades in southeastern Indiana. Discovery of any glade should be reported, incorporating location information and a species list, to the Division of Nature Preserves, Department of Natural Resources.

Acknowledgments

The author would like to express his gratitude to John Bacone, Lee Casebere, Barbara Homoya, and Jerrie Worthy, for their contributions to this paper. The support of the Department of Natural Resources is also appreciated.

Literature Cited

1. Aldrich, J.R., J.A. Bacone, and M.A. Homoya. 1986. List of extirpated, endangered, threatened, and rare vascular plants of Indiana: an update. Proc. Indiana Acad. Sci. 95: 413-419.
2. ______, J.A. Bacone, and M.D. Hutchison. 1982. Limestone glades of Harrison County, Indiana. Proc. Indiana Acad. Sci. 91: 480-485.

3. Bacone, J.A., L.A. Casebere, and M.D. Hutchison. 1983. Glades and barrens of Crawford and Perry Counties, Indiana. Proc. Indiana Acad. Sci. 92: 367-373.
4. ______, L.A. Casebere, and M.D. Hutchison. 1984. Glades of the Knobstone Escarpment in Indiana. Proc. Indiana Acad. Sci. 93: 303-307.
5. Baskin, J.M. and C.C. Baskin. 1985. A floristic study of a cedar glade in Blue Licks Battlefield State Park, Kentucky. Castanea 50: 19-25.
6. General Land Office survey records for Indiana. 1799-1834 Vol. 1-8. Archives, Indiana State Library, Indianapolis.
7. Homoya, M.A., D.B. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Proc. Indiana Acad. Sci. 94: 245-268.
8. Jackson, M.T. and P.R. Allen. 1969. Detailed studies of old-growth forests in Versailles State Park, Indiana. Proc. Indiana Acad. Sci. 78: 210-230.
9. Maxwell, R.H. 1986. Natural area remnants within the Indiana Army Ammunition Plant, Charlestown, Indiana. Proc. Indiana Acad. Sci. 95: (abstract).
10. McWilliams, K.M. 1985. Soil Survey of Ripley County and Part of Jennings County, Indiana. U.S.D.A. Soil Conservation Service, Washington, D.C. 125 p.
11. Potzger, J.E. 1950. Forest types in the Versailles State Park area, Indiana. Amer. Midland Nat. 43: 729-741.
12. Rexroad, C.B. 1975. Versailles Park — where history, geology, and nature meet. Outdoor Indiana 40: (October) 4-12.
13. Stearns, F. 1956. Forest communities in Versailles State Park, Indiana. Butler Univ. Bot. Stud. 13: 85-94.
14. White, J. and M.H. Madany. 1978. Classification of natural communities in Illinois, pp. 309-405 *in* John White, Illinois Natural Areas Inventory Technical Report. Ill. Nat. Areas Inventory. Urbana, Illinois.

Natural Area Remnants within the Indiana Army Ammunition Plant, Charlestown, Indiana: The Little Bluestem Glades

Richard H. Maxwell
Indiana University Southeast Herbarium
New Albany, Indiana 47150

Introduction

In 1975 I began a botanical survey in the Indiana Army Ammunition Plant (IAAP) in Clark County with permission from the U.S. Army (17). Of the ammunition plant's 20,000 acres, the survey covers about 1,400, mostly undeveloped, acres at the north end and both sides of Fourteen Mile Creek. Work with Indiana Natural Heritage Program biologists resulted in the identification of several endangered and threatened species (2,3) and recognition of two little bluestem glades as distinct habitats from the general upland region south of Fourteen Mile Creek. Little bluestem dominates both glades as a xeric, bunch-grass surrounded by patches of rocky pavement. There are other cedar limestone glades in the area; unless noted, the term glades used below refers to the two little bluestem glades. A list of species found follows with discussion of why the glades are of interest.

Methods

Collections and visits have been made throughout the growing season since 1975. Nineteen trips were made to the glades in 1986.

Identification of possible glades within the IAAP were made by the Indiana Division of Natural Resources, Natural Heritage Program, using air photos (1,4,5) followed by ground surveys by Natural Resources ecologists. ICI Americas, Inc. (operating contractor), provided air photos from June 23, 1949, June 8, 1960, and June 13, 1968.

In 1986, 29 quadrat measurements were made. A transect of quadrats was taken on the south facing slope of the west glade as well as were random quadrats. Soil depths of both glades were determined by digging with a ditching spade about every meter downslope along transect lines.

Collection vouchers are deposited in the Indiana University Herbarium at Bloomington (IND). Some species, as noted, were only observed. A voucher list, including some field notes, is available from the author upon request.

Results

Species of the Open Glades — Vascular Plants

Collection dates of vouchers are given. Species occur in the open rocky pavement area between bunches of little bluestem. The nomenclature is from Gleason (13), unless noted.

OPHIOGLOSSACEAE

Ophioglossum engelmannii Prantl. 7 June, 1984.

CUPRESSACEAE

Juniperus virginiana L. 4 Oct., 1985.

POACEAE

Panicum flexile (Gatt.) Scribn. 12 Sept., 1986.

Andropogon scoparius Michx. (*Schizachyrium scoparium* (Michx.) Nash. (18)). 17 Sept., 1979.

Sporobolus vaginiflorus (Torr.) Wood. 4 Oct., 1985.

Sorghastrum nutans (L.) Nash. Oct., 1985.

CYPERACEAE

Eleocharis elliptica Kunth. var. *compressa* (Sull.) Drap. & Mohl. (18) (*E. compressa* Sulliv. (13)). 17 May, 1984.

Carex hirsutella Mack. (18) (*C. camplanata* Torr. & Torr. var. *hirsuta* (Bailey) Gl. (13)). 30 June, 1980.

LILIACEAE

Allium cernuum Roth. 20 July, 1979.

Agave virginica L. 8 Aug., 1984.

IRIDACEAE

Sisyrinchium albidum Raf. 19 May, 1980.

ORCHIDACEAE

Spiranthes magnicamporum Sheviak (18). 10 Oct. 1985.

FAGACEAE

Quercus muhlenbergii Engelm. (18).

RANUNCULACEAE

Thalictrum revolutum DC. 20 July, 1979.

CRUCIFERAE

Draba verna L. 14 March, 1980.

Leavenworthia uniflora (Michx.) Britt. (13). 15 April, 1981.

FABACEAE

Cassia fasciculata Michx. 8 Sept., 1980.

Lespedeza sp. 10 Oct., 1986.

Galactia volubilis (L.) Britt. var. *mississippiensis* Vail. 17 Sept., 1979.

LINACEAE

Linum sulcatum Riddell. 8 Sept., 1980.

POLYGALACEAE

Polygala verticillata L. 6 Aug., 1986.

EUPHORBIACEAE

Croton monanthogynus Michx. 8 Sept., 1980.

Euphorbia corollata L. 15 July, 1986.

RHAMNACEAE

Rhamnus caroliniana Walt. (18)

CACTACEAE

Opuntia compressa (Salisb.) Macbr. June.

PRIMULACEAE

Dodecatheon meadia L. 8 May, 1986.

OLEACEAE

Fraxinus sp. Observed.

GENTIANACEAE

Sabatia angularis (L.) Pursh. 15 July, 1986.

APOCYNACEAE

Apocynum cannabinum L. Observed.

ASCLEPIADACEAE

Asclepias viridiflora Raf. 6 Aug., 1986.

Asclepias verticillata L. 31 July, 1985.

BORAGINACEAE

Heliotropum tenellum (Nutt.) Torr. 26 June, 1981.

Lithospermum canescens (Michx.) Lehm. 1 May, 1979.

VERBENACEAE

Verbena simplex Lehm. 31 July, 1981.

LABIATAE

Isanthus brachiatus (L.) BSP. 1 Sept., 1984.

Scutellaria parvula Michx. var. *leonardii* (Epling) Fern. (18) (*S. leonardi* Epl. (13)). 4 June, 1980.

Salvia lyrata L. 23 Sept., 1977.

Blephilia ciliata (L.) Benth. 4 June, 1980.

Hedeoma hispida Pursh. 4 June, 1980.

SOLANACEAE

Physalis virginiana Mill. 4 June, 1980.

Solanum carolinense L. 13 Aug., 1986.

SCROPULARIACEAE

Conobea multifida (Michx.) Benth. (*Leucospora multifida* (Michx.) Nutt. (18)). 26 July, 1985.

Gerardia tenuifolia Vail. 17 Sept., 1979.

ACANTHACEAE

Ruellia humilis Nutt. 8 Sept., 1980.

RUBIACEAE

Houstonia longifolia Gaertn. var. *ciliolata* (Torr.) Torr. (18) (*H. canadensis* Willd. (13)). 24 May, 1984.

CAPRIFOLIACEAE

Symphoricarpos orbiculatus Moench. Sept. Observed.

CAMPANULACEAE

Lobelia spicata Lam. 17 Sept., 1979.

COMPOSITAE

Ambrosia artemisiifolia L. 1 Sept., 1984.

Aster pilosus Willd. 11 Oct., 1985.

Erigeron strigosus Muhl. June-July. Observed.

Solidago nemoralis Ait. 12 Sept., 1986.

Noted also is the presence of mats of blue-green algae on unshaded rock surface (20) and open rocky pavement. See Quarterman (20) for the role of these algae as well as bryophytes and lichens in cedar glade successcion.

Juniperus virginiana is common on the open glades and sets seed. *Quercus muhlenbergii*, *Rhamnus caroliniana*, *Celtis occidentalis* L., *Quercus coccinea* Muench., *Q. rubra* L., *Fraxinus spp.* (probably blue and green ash), *Acer saccharum* Marsh., and *Cercis canadensis* L. appear in the open glades, but are stunted or do not survive. A few plants of *Rubus* sp. have also come in, but rarely exceed 25 cm and have never flowered.

The following species are believed to be invading the little bluestem glade community from surrounding habitats. Some of these species are included as glade species on published glade lists (1,6,7,8,10): *Anemone virginiana* L., 25 July, 1986; *Chrysanthemum leucanthemum* L. var. *pinnatifidum* LeCoq & Lamotte, 1 Aug., 1986; *Cirsium discolor* (Muhl.) Spreng., 13 Aug., 1986; *Convolvulus spithameus* L., 4 June, 1980; *Daucus carota* L., 1 Aug., 1986; *Eupatorium altissimum* L. Aug.-Oct.; *Euphorbia dentata* Michx., July; *Desmanthus illinoensis* (Michx.) MacM., 1 Aug., 1986; *Dasostoma macrophylla* (Nutt.) Raf. (13) (*Seymeria macrophylla* Nutt. (18)), 23 July, 1986; *Hexalectris spicata* (Walt.) Bernh., 25 July, 1986; *Hypoxis hirsuta* (L.) Coville, May, observed; *Lepidium virginicum* L., May, observed; *Lonicera japonica* Thunb., observed; *Panicum sp.*, Aug., observed; *Smilax sp.* Oct., observed; *Tridens flavus* (L.) Hitchcock (18). Sept.; *Thlaspi arvense* L., May, observed.

Discussion

The glaciated (16) upland region of Clark County to either side of Fourteen Mile Creek is in the Muscatatuck Flats and Canyons Section of the natural regions of Indiana (15). About 25 acres of this region west and south of Fourteen Mile Creek contain shallow wooded ravines, dry wooded sinkholes, open rocky woods and limestone cedar glades (9). The glades include an open meadow grass glade, a disrupted waste glade and the two adjacent little bluestem glades. All the glades contain populations of *Leavenworthia uniflora* Michx., and to my knowledge these are the only sites of *L. uniflora* in Indiana (11,12).

The soil is Crider silt loam, an upland soil formed in loess over weathered, chert-free, thin-bedded limestone (19). The flatter upland portion with deeper soil is disrupted by rampant growth of Japanese honeysuckle. In shallow soils, showing expanses of fossiliferous bare rock and coarse gravel, combinations of cedar glade species appear.

The areas described above, have been, for the most part, greatly disturbed. The little bluestem glades are the least disturbed remnants. Disturbance has been caused by grazing, possibly cultivation, various kinds of construction, wood cutting, conservation group activities, and summer exercises by tanks and armored units from Ft. Knox, Kentucky. These activities have not occurred for several years. The only current disturbance is deer browsing. The most serious damage to these communities has been done by the introduction of alien, noxious species, such as Japanese honeysuckle, tree of heaven, multiflora rose and various fescue grasses.

The little bluestem glades are east of IAAP Gate 26 and Jersey Avenue. The west end of the west glade is separated by the extension of Jersey Avenue and has been disrupted by past construction. The somewhat U-shaped west glade slopes at 19.4-21.3% from SSW through S to SE and covers about 1.8 acres. It contains several tree islands. This glade ends to the south in rocky, mostly cedar woods. Here the soil becomes Corydon stony silt loam on 25 to 70% slopes (19). These steep slopes fall to the rock bed of Lick Creek.

The somewhat rectangular 0.9 acre east glade has a west-facing 18.5% slope. A rocky, intermittent stream lined with cedars separates the 2 glades.

Neither glade shows erosion. The soil is fairly dark, indicating the accumulation of humus. The soil depths of 0-8-12 cm in both is consistent with the Baskins' characterization of the deep-soil community (9).

A comparison of these glades with the Bullitt County, Kentucky, glades shows striking similarity. The Baskins list 15 characteristic cedar glade species with the outcrop classified as an undisturbed cedar glade if 10 of the 15 are present (7). The Bullitt County sites are about 30 miles due south of the little bluestem glades.

Species characteristic of the Bullitt Co. glades from the Baskins' list, but found in the little bluestem glades, are *Ruellia humilis*, *Agave virginica*, *Isanthus brachiatus*, *Ophioglossum engelmannii*, *Sporobolus vaginiflorus*, *Heliotropium tenellum*, *Scutellaria parvula*, *Houstonia canadensis* (13) (*H. canadensis* Willd. = *H. longifolia* Gaert. var. *ciliolata* (Torr.) Torr. (18)), *Sisyrinchium albidum*, *Asclepias verticillata* and *Croton monanthogynus*.

Listed by Baskin and Baskin, but not found in the little bluestem glades, are *Viola egglestonii* and *Leavenworthia exigua* var. *laciniata*, both endemic to southern cedar glades (7). No *Viola* species has been found in the little bluestem glades. The *Leavenworthia* is *L. uniflora*, not *L. exigua*, although Baskin and Baskin (7) note a collection of *L. exigua* in Jefferson County, Kentucky, about 20 miles south of the Clark County glades. Also absent is *Houstonia nigricans* (Lam.) Fern. and *Northoscordum bivalve* (L.) Britt. *Houstonia nigricans* has been found in the Harrison County glades (1), and *N. bivalve* may be more common in southern Indiana than current records show (12), but neither species has been positively determined from the IAAP.

The Baskins collected a total of 77 species from cedar glades in Bullitt County (7). To date, 55 of those have been found and determined from the little bluestem glades. Collections from all IAAP gladelike areas will exceed 77 and I consider this an indication of disturbance.

A comparison of the little bluestem glade species with Harrison County, Indiana, limestone glade species (1), shows a similarity of only about 46%. However, the Harrison County glades are in the Mitchell Plain Physiographic Province (1) (Mitchell Karst Plain Section (15)), a different natural region. Also, several Harrison County species, such as *Anemonella thalictroides*, *Pelea atropurpurea*, *Rhus aromatica*, *Hexalectris spicata*, *Houstonia purpurea*, *Hypoxis hirsuta*, *Menispermum canadense*, *Viburnum rufidulum* and *Viola triloba*, are found in the rocky open woods surrounding the glades. The Harrison County glades are about 60 miles from the IAAP.

Probably of greater importance in comparing the Indiana sites is the absence of a significant composite-prairie component in the IAAP glades. Found in Harrison County (1), but absent at the IAAP are *Andropogon gerardii* (4,8,14,21,22), *Echinacea purpurea*, (8,18) *Eryngium yuccaefolium* (4,8,14,21,22), *Ratibida pinnata* (4,6,7,21), all *Liatris* (4,6,8,14,18,21,22), *Kuhnia eupatorioides* (6,8,14,21) and the prairie rosinweeds (4,7,8,14,18,21). A comparison of these species would seem to show that the IAAP glades have a stronger community affinity with Kentucky and southeastern glades than western prairie types; or that the probable lack of burning in the IAAP glades has eliminated prairie species maintained by fire.

Although knobstone escarpment glades in Clark and Floyd Counties may be closer geographically, the Knobstone Escarpment Section is a different natural region (15) and the checklist (5) indicates a different community structure than the IAAP glades.

The glades as relic components of barrens or prairies of southern Indiana have been discussed by Aldrich, Bacone, and Hutchinson (1).

Succession as observed in the glades and surrounding woods is apparently similar to that described by Quarterman (20) in Tennessee cedar glades. Possible sub-climaxes involve use of the glades as cultivated fields as well as for heavy grazing. The June 23, 1949, air photo shows the area of approximately 25 acres fenced into small fields; one fence remnant is still evident at the south end of the east glade. While it is unlikely slopes containing such submarginal soils were ever farmed, it is possible that this might have occurred with soils eroding down to the bedrock, little bluestem coming in, the community re-established and succession continuing. Little bluestem has been observed growing on discarded chunks of concrete in the west glade. See also Jones' study of abandoned prairie in Ohio (14).

A second sub-climax mentioned by Quarterman involved red cedar becoming established in rock crevices (20). At the IAAP this pioneer role is shared by *Quercus muhlenbergii*, the largest trees in each tree island as well as the rocky woods surrounding the glades. Characteristically some of their roots are above the rocky soil for 1-2 meters from the trunk. From observations over the last few years, we feel the red cedars in the west glade will eventually form a closed stand progressing to the current community of the surrounding rocky woods, a pattern noted by Quarterman (20). We have not observed as much change in the cedars of the east, west-facing glade.

Regardless of the fate of the glades, I believe they are unique to Indiana. Using Baskin and Baskin's criteria species list (7), the little bluestem glades share enough species to be classified as undisturbed. Invasion by alien and weedy species is minimal. The darker soil of the little bluestem glades also indicates a period of humus accumulation and a lack of erosion. The aerial photograph of June 6, 1949, compared with that of June 13, 1968, and our current field observations show a remarkable preservation of the glades proper. The photos taken in June when the leaves are out, enable us to identify marker oaks to assess glade shrinkage. I certainly recommend that efforts be continued to preserve these natural remnants.

Acknowledgments

I wish to thank Jim Aldrich and Jerry Baskin for their encouragement; I am also indebted to Jerry for reading the manuscript. Field knowledge shared by Cloyce Hedge, Jim Aldrich, John Bacone, Jerry and Carol Baskin, Tom Post, Helene Starcs, and Mike Homoya is gratefully appreciated. I thank a succession of Commanding Officers and their Executive Offices for annual permission to enter the IAAP restricted areas. I also thank ICI Americas, especially Walt McClellan, and their security force for their unfailing cooperation, Lewis Johnson, George Yatskievych and Kay McCrary for help with determinations and securing the vouchers at Indiana University, Bloomington.

Part of this work was done while on a Summer Faculty Fellowship, 1986, from Indiana University Southeast. Gerald Ruth did the surveying.

Literature Cited

1. Aldrich, J.R., J.A. Bacone and M.D. Hutchinson. 1981. Limestone glades of Harrison County, Indiana. Proc. Indiana Acad. Sci. 91:480-485.
2. Bacone, J.A. and C.L. Hedge. 1980. A preliminary list of endangered and threatened vascular plants in Indiana. Proc. Indiana Acad. Sci. 89:359-371.
3. Bacone, J.A., T.J. Crovello and C.L. Hedge. 1981. The status of Indiana's rare plants: A revision of the list of the endangered and threatened vascular plants. Proc. Indiana Acad. Sci. 90:385-387.
4. Bacone, J.A., L.A. Casebere and M.D. Hutchinson. 1983. Glades and barrens of Crawford and Perry Counties, Indiana. Proc. Indiana Acad. Sci. 92:367-373.
5. Bacone, J.A., L.A. Casebere and M.D. Hutchinson. 1984. Glades of the Knobstone Escarpment in Indiana. Proc. Indiana Acad. Sci. 93:303-307.
6. Baskin, J.M., E. Quarterman & C. Caudle. 1968. Preliminary check-list of the herbaceous vascular plants of cedar glades. J. Tenn. Acad. Sci. 43(3):65-71.
7. Baskin, C.C. and J.M. Baskin. 1975. The cedar glade flora of Bullitt County, Kentucky. Castanea 40:184-190.
8. Baskin, J.M. and C.C. Baskin. 1978. Plant ecology of cedar glades in the big barren region of Kentucky. Rhodora 80(824):545-557.
9. Baskin, J.M. & C.C. Baskin. 1985. Life cycle ecology of annual plant species of cedar glades of southeastern United States. 317-398. In: White, J. ed. The Population Structure of Vegetation. W. Junk Publishers, Dordrecht.
10. Baskin, J.M. & C.C. Baskin. 1985. A floristic study of a cedar glade in Blue Licks Battlefield State Park, Kentucky. Castanea 50(1):19-25.
11. Baskin, J.M. & C.C. Baskin. 1986. Distribution and geographical/evolutionary relationships of cedar glade endemics in southeastern United States. ASB Bull. 33(4):138-154.
12. Deam, C.C. 1940. Flora of Indiana. Dept. Cons., Div. Forestry, Indianapolis, 1236 p.
13. Gleason, H.A. & A. Cronquist. 1963. Manual of Vascular Plants of Northeastern States and Adjacent Canada. D. Van Nostrand Company, Inc., Princeton, N.J. 810 p.
14. Jones, C.H. 1944. Studies in Ohio floristics-III. Vegetation of Ohio prairies. Bull. Torr. Bot. Club 71(5):536-548.
15. Homoya, M.A., D.B. Abrell, J.R. Aldrich and T.W. Post. 1985. The natural regions of Indiana. Proc. Indiana Acad. Sci. 94:245-268.
16. Malott, C.A. 1925. The glacial boundary in Indiana. Proc. Indiana Acad. Sci. 35:93-107.

17. Maxwell, R.H. 1985. Natural areas remnants within the Indiana Army Ammunition Plant, Charlestown, Indiana. Presentation, Fall Meeting, Indiana Acad. Sci.
18. Mohlenbrock, R.H. 1975. Guide to the Vascular Flora of Illinois. Southern Illinois University Press, Carbondale, Illinois. 494 p.
19. Nickell, A.K. 1974. Soil survey of Clark and Floyd Counties, Indiana. USDA Soil Cons. Serv., U.S. Forestry Service and Purdue Univ. Agric. Exp. Sta.
20. Quarterman, E. 1950. Major plant communities of Tennessee cedar glades. Ecology 31:234-254.
21. Weaver, J.E. 1954. North American Prairie. Johnsen Publishing Co., Lincoln Nebraska. 348 p.
22. Wistendahl, W.A. 1975. Buffalo Beats, a relic prairie within a southeastern Ohio forest. Bull. Torr. Bot. Club 102(4):178-186.

Comparison of Groundlayer and Shrublayer Communities in Full Canopy and Light Gap Areas of Hoot Woods, Owen County, Indiana

Rebecca A. Strait and Marion T. Jackson
Department of Life Sciences
Indiana State University
Terre Haute, Indiana 47809
and
D. Brian Abrell
Indiana Department of Natural Resources
Indianapolis, Indiana 46204

Introduction

Hoot Woods is a 64-acre (25.9-ha) old-growth beech-maple dominated forest located in Owen County, Indiana, about 3 miles northwest of the village of Freedom. The tract occupies a gentle east-facing slope which closely approximates the average environment for that region. Predominate soils are residual Wellston and Muskingum silt loams (35-70% slopes) and Zanesville silt loam (12-18% slope) derived in sandstone and shale (Owen County Soil Survey Report). National Natural Landmark designation was awarded the stand several years ago in recognition of its overall high quality and lack of disturbance.

Forest composition and stand dynamics of Hoot Woods have been the focus of several studies (Petty and Lindsey, 1961; Jackson and Allen, 1967; Donselman, 1973; Levenson, 1973; Williamson, 1975; Abrell and Jackson, 1977; and Jackson and Abrell, 1977).

A 10.87-acre (4.40-ha) area within the best section of the stand was fully censused for forest trees and all stems > 4.0 inches (10 cm) dbh mapped at a 1:33 scale during the summer of 1965 (Jackson and Allen, 1967). An additional 5.43-acre (2.20-ha) adjoining area was mapped during the decade interval follow-up study by Abrell and Jackson (1977) bringing the total area under consideration to 16.30 acres (6.60-ha).

During August 1979, the high-canopied stand (ca. 120 ft. or 37 m) was extensively damaged by tornadic force winds. Three major storm tracts were opened west-east across the mapped portion of the woods. In extensive areas all trees were uprooted, twisted off or seriously damaged. The stand also suffered a number of single or multiple tree falls, plus extensive damage to sections of the woods not the subject of intensive study.

Creation of light gaps by windthrow and other natural processes such as insect damage, disease and tree mortality due to age is a mechanism for retaining successional species within the stand, and for producing compositional mosaics even in older growth forests. The subject of this paper is the comparison of groundlayer and shrublayer communities in the full-canopied and light gap areas of the stand following six growth seasons after disturbance.

Methods

The 16.30-acre (6.60-ha) area was divided into 96 plots each 86 ft. (26.2 m) square. Thirty-two of these plots were selected as groundlayer community sample sites, with the shrublayer community sampled at these 32 locations, plus an additional 8 plots. Density, frequency and cover values were taken for groundlayer species within 1 × 1 m plots centered at the midpoint of the large tree plots. Shrub species were likewise sampled in 3 × 3 m plots at the same locations. Plot centers were permanently marked with sections of ¾-inch diameter electrical conduit. An effort was made to have one-half of each group of samples located in plots covered by full canopy and in plots within light gap areas.

Groundlayer plants were considered to be any vascular species (both herbaceous and woody) less than ½ m tall. Densities of above-ground stems, frequency percentages and subjective vegetation cover determinations were taken for all species present during Spring and Late Summer (late August) for groundlayer species. Shrublayer communities included all woody plants > ½ m < 3 m tall. Similar data were taken for shrubs in Mid-Summer (July) of the 1986 growth season. Percentage of groundlayer plants flowering was also recorded.

Chi-square values were calculated to determine differences in species densities between canopied and light gap areas in each of the sampled communities.

Species importance percentages were determined by averaging relative density, relative cover and relative frequency values for each species.

Results

Groundlayer Community Composition

Species attributes for the Spring and Late Summer sampling periods are listed in Tables 1 and 2, respectively. Considering the apparent ecological differences between the full canopy and light gap areas, and the time elapsed since disturbance (6 growth seasons) the Spring Communities are remarkably similar (Table 1). Each community contained 27 species, with a total of 33 species represented in the two communities combined. Only *Dicentra cucullaria* of the top 18 species was not common to both communities. Eleven species were woody, only two were ferns, plus one each grass and sedge species.

TABLE 1. Comparison of species attributes for the Groundlayer Communites during the Spring sample (based on 17 plots each 1 × 1 m in canopy community, and 15 plots in light gap community).

	Density/m^2		Relative Cover		% Importance		
Species	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Deviations in % Importance
Dicentra canadensis (Goldie) Walp.	45.71	48.80	26.33	34.69	19.74	26.54	+6.80
Erythronium americanum Nutt.	48.65	43.87	13.91	13.55	17.23	17.57	+0.34
Podophyllum peltatum L.	3.35	4.27	17.19	16.50	8.11	8.02	−0.09
Acer saccharum Marsh.	5.65	3.20	8.65	7.39	7.44	6.26	−1.18
Dentaria laciniata Muhl.	12.48	3.80	1.81	1.24	5.74	3.85	−1.89
Claytonia virginica L.	8.12	5.80	1.31	1.25	4.78	4.83	+0.05
Impatiens spp. L.	5.41	6.47	3.65	7.02	4.41	6.14	+1.73
Cystopteris fragilis (L.) Bernh.	12.18	4.00	4.08	1.88	4.01	2.07	−1.94
Brachyelytrum erectum (Schreb.) Beauv.	12.06	0.60	4.57	0.45	3.94	0.80	−3.14
Viola papilionacea Pursh.	6.12	5.40	1.33	1.27	3.54	3.47	−0.07
Dicentra Cucullaria (L.) Bernh.	4.41	—	4.88	—	3.53	—	−3.53
Arisaema triphyllum (L.) Schott.	5.48	2.00	0.80	1.53	2.36	2.24	−0.12
Galium asprellum Michx.	1.24	3.27	2.43	3.48	2.36	3.70	+1.34
Laportea canadensis (L.) Wedd.	3.12	3.73	2.88	3.17	2.19	2.44	+0.25
Erigenia bulbosa (Michx.) Nutt.	1.35	0.80	0.08	0.03	1.82	0.71	−1.11
Parthenocissus quinquefolia (L.) Planch.	1.24	1.33	1.15	1.02	1.71	2.43	+0.72
Rubus allegheniensis Porter.	0.18	1.00	0.36	3.17	0.37	2.05	+1.68
Viola eriocarpa Schw.	0.12	0.93	0.19	0.53	0.52	1.16	+0.64
[1]Other species	6.46	3.27	4.37	1.89	6.17	5.72	−0.45
Total	183.33	142.54	99.97	100.04	99.97	100.00	

[1] Other species in descending order of importance: Ulmus rubra Muhl., Phytolacca americana L., Polystichum acrostichoides (Michx.) Schott., Galium sp. L., Carex sp. L., Lindera Benzoin (L.) Blume., Cornus florida L., Ulmus americana L., Fagus grandifolia Ehrh., Prunus serotina Ehrh., Fraxinus sp. L., Solidago sp. L., Asimina triloba (L.) Dunal., Trillium sp. L., Isopyrum biternatum (Raf.) T. & G.

Chi Square value for density comparison for top 7 species is 8.901, 6df; not significant at 0.05 level.

Total mean density per square meter was significantly higher in the Spring full canopy samples than in the light gaps at 183.33 versus 142.54 (Chi-square 1.08, ldf) (Table 1). *Dicentra canadensis* and *Erythronium americanum* were codominant in both Full Canopy and Light Gap communities at combined importances of 37% and 44%, respectively. The top four species were the same order in both communities, with only minor shifts in order among the top eight species. The top eight species had very closely similar combined importances of 71.5 and 75.3%, respectively, in the two communities (Table 1).

Total mean density per square meter values for the Late Summer Community were only 9 and 15% of the Spring Community totals at 16.84 and 21.87, respectively (Table 2). The Full Canopy and Light Gap Communities contained only 18 and 13 species, respectively. *Acer saccharum* seedlings and *Pilea pumila* were dominant in both cases at a combined importance of 60 and 67%, in the Full Canopy and Light Gap Communities, respectively. The most dramatic change between communities was the nearly double increase in importance for *Pilea pumila* in the Light Gap Community (from 28.70 to 53.41%) (Table 2). Woody species comprised a much larger portion of the fall sample at 47.2 and 22.9% in the Full Canopy and Light Gaps, respectively.

TABLE 2. Comparison of species attributes for the Groundlayer Communities during the Late Summer sample (based on 17 plots each 1 × 1 m in canopy community, and 15 plots in light cap community).

	Density/m²		Relative Cover		% Importance		
Species	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Deviations in % Importance
Acer saccharum Marsh.	5.65	1.40	31.04	16.37	31.12	13.44	−17.68
Pilea pumila (L.) Gray.	5.23	14.33	32.87	55.85	28.70	53.41	+24.71
Polystichum acrostichoides (Michx.) Schott.	2.12	—	8.88	—	7.88	—	− 7.88
Laportea canadensis (L.) Wedd.	1.76	1.20	7.01	23.50	7.30	12.13	+ 4.83
Carya cordiformis (Wang.) K. Koch.	0.12	—	5.61	—	3.58	—	− 3.58
Galium sp. L.	0.41	0.93	0.14	0.13	3.08	4.99	+ 1.91
Asimina triloba (L.) Dunal.	0.06	—	5.61	—	2.73	—	− 2.73
Fraxinus sp. L.	0.18	—	0.14	—	2.62	—	− 2.62
Cornus florida L.	0.24	—	2.81	—	2.14	—	− 2.14
Lindera Benzoin (L.) Blume.	0.12	—	2.81	—	1.91	—	− 1.91
Sassafras albidum (Nutt.) Nees.	0.12	—	1.40	—	1.44	—	− 1.44
Viola papilionacea Pursh.	0.29	0.20	0.05	0.04	1.34	1.47	+ 0.13
Fagus grandifolia Ehrh.	0.06	—	1.40	—	1.32	—	− 1.32
Cystopteris fragilis (L.) Bernh.	0.18	0.67	0.05	0.04	1.10	1.24	+ 0.14
Ulmus americana L.	0.12	0.13	0.05	2.52	0.99	2.18	+ 1.19
Prunus serotina Ehrh.	0.06	—	0.05	—	0.87	—	− 0.87
Epifagus virginiana (L.) Bart.	0.06	—	0.05	—	0.87	—	− 0.87
Parthenocissus quinquefolia (L.)	0.06	0.67	0.05	0.04	0.87	1.24	+ 0.37
Acer rubra L. Planch.	—	0.40	—	0.08	—	2.94	+ 2.94
Circaea quadrisulcata (maxim) Franch. & Sav.	—	0.20	—	0.08	—	2.60	+ 2.60
Smilax hispida Muhl.	—	0.67	—	1.26	—	1.65	+ 1.65
Rubus flagellaris L.	—	0.20	—	0.04	—	1.47	+ 1.47
Phytolacca americana L.	—	0.67	—	0.04	—	1.24	+ 1.24
Totals	16.84	21.87	99.97	99.99	99.86	100.00	

Groundlayer Flowering Rates

The percentage of above ground stems which flowered were computed for each the Spring and Late Summer groundlayer communities (Table 3). Most species had very low flowering rates with 10 of 14 species in the Spring Full Canopy Community and 7 of

TABLE 3. Comparison of flowering data for herbaceous groundlayer species during the Spring and Late Summer sample periods.

	Full Canopy		Light Gaps	
Species	No. Flowering	% Flowering	No. Flowering	% Flowering
Spring Community				
Dicentra canadensis	2/777	0.26	7/732	0.96
Erythronium americanum	3/827	0.36	1/658	0.15
Podophyllum peltatum	1/57	1.75	1/64	1.56
Impatiens spp.	0/92	0	0/97	0
Dentaria laciniata	1/212	0.47	9/57	15.78
Claytonia virginica	98/138	71.01	24/87	27.59
Brachyelytrum erectum	4/205	1.95	—	—
Viola papilionacea	0/104	0	1/81	1.23
Galium asprellum	19/21	90.48	12/49	24.49
Dicentra cucullaria	0/75	0	—	—
Arisaema triphyllum	0/93	0	0/30	0
Laportea canadensis	0/53	0	0/56	0
Erigenia bulbosa	7/23	30.43	—	—
Viola eriocarpa	1/1	100.00	6/14	42.86
Late Summer Community				
Pilea pumila	62/89	69.66	138/215	64.19
Laportea canadensis	4/30	13.33	4/18	22.22
Galium sp.	1/7	14.28	1/14	7.14
Circea quadrisulcata	—	—	0/3	0
Viola papilionacea	0/5	0	0/3	0
Phytolacca americana	—	—	0/1	0
Epifagus virginiana	0/1	0	—	—

11 species in the Spring Light Gaps Community registering less than 2% of above ground stems which flowered (Table 3). In eight of these cases, there wsa no flowering for species represented by 30 or more individuals. Only *Claytonia virginica* and *Galium asprellum* of higher density species had flowering rates above 50%. In general, flowering rates for the Light Gaps Community were low also, with *Claytonia* and *Galium* showing marked reductions. Only *Dentaria laciniata* experienced a marked increase in flowering in the Light Gaps.

The Late Summer Community had too few individuals for several species for meaningful comparison. The dominant species, *Pilea pumila* had about ⅔ of the stems flowering, with *Laportea canadensis* ranging from 13 to 22% flowering (Table 3). No major differences were noted between Full Canopy and Light Gap areas.

Shrub Community Composition

Species attributes for shrub species for both the Fall Canopy and Light Gaps Communities are summarized in Table 4. Slightly more species comprised the Full Canopy (20 *versus* 17); whereas the Light Gaps Community had a higher total density (263 *versus* 195). *Asimina triloba* dominated both communities similarly at 33.6 and 36.9 percent importance, respectively (Table 4). The most notable difference between the two communities is the addition of *Rubus allegheniensis* at 14.6 percent importance in the Light Gap community, reflecting the invasion potential of blackberry into the high-light openings. Other than the difference in *Rubus*, the top four species had combined importance percentages in the two communities of 75.5 and 62.6, respectively (Table 4).

Tree seedlings comprised a very similar combined importance of 41.7 and 39.3 percent, respectively, with the very tolerant *Acer saccharum* and *Fagus grandifolia* both being well represented in both communities, but at reduced density and cover values in

TABLE 4. Comparison of species attributes for the Shrub Community during Midsummer sample (based on 20 3 × 3 m plots in each community).

	Density/20 plots		Relative Cover		% Importance		
Species	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Full Canopy	Light Gaps	Deviations in % Importance
Asimina triloba (L.) Dunal.	66	84	51.93	59.18	33.55	36.85	+ 3.30
Acer saccharum Marsh.	39	30	16.56	9.64	18.04	12.57	− 5.47
Rubus allegheniensis Porter.	—	78	—	7.24	—	14.61	+ 14.61
Lindera Benzoin (L.) Blume	26	7	13.53	5.54	13.46	5.05	− 8.41
Fagus grandifolia Ehrh.	18	18	8.50	5.11	10.41	8.15	− 2.26
Cornus florida L.	8	3	5.42	2.01	5.43	1.98	− 3.45
Fraxinus Spp. L.	11	7	1.37	1.63	5.04	2.82	− 2.22
Ulmus rubra Muhl.	7	18	0.29	5.73	2.64	8.82	+ 6.18
Carya cordiformis (Wang.) K. Koch.	5	6	0.34	0.97	2.32	2.94	+ 0.62
Quercus Muehlenbergii Michx.	2	—	0.20	—	1.31	—	− 1.31
Carya ovata (Mill.) K. Koch	2	—	0.98	—	1.12	—	− 1.12
Sassafras albidum (Nutt.) Nees	2	3	0.05	2.01	0.81	1.98	+ 1.17
Liriodendron tulipifera L.	—	3	—	0.66	—	1.99	+ 1.99
[1]Other species	9	6	0.83	0.28	5.89	2.24	− 3.65
Total	195	263	100.00	100.00	100.02	100.00	

[1] Other species in descending order of importance in *Full Canopy*: Sambucus canadensis L., Morus rubra L., Ostrya virginiana (Mill.) K. Koch., Vitis sp. L., Prunus serotina Ehrh., Smilax hispida Muhl., Quercus alba L., Quercus rubra L., Cercis canadensis L.; Species richness: 20

Other species in descending order of importance in *Light Gap*: Prunus serotina Ehrh., Vitis sp. L. Smilax hispida Muhl., Sambucus canadensis L., Parthenocissus quinquefolia L. Planch., Rubus occidentalis L. Species richness: 17

Chi-square for species in common = 45.267, 8 df.

the Light Gaps (Table 4). Riemenschneider and Blodgett (1984) also found little change in tree regeneration due to windthrow disturbance in Bendix Woods. *Cornus florida* was present in both communities, but again at lower incidence in the Light Gaps. Wind dispersed and intolerant *Liriodendron tulipifera* seedlings were present only in Light Gaps samples. *Ulmus rubra*, also wind dispersed and frequently aggressively invading in disturbance sites was present in the Light Gaps at three times its importance in the Full Canopy Community (Table 4). Chi-square values for densities of the 9 species in common to both communities showed significant differences (Chi-square = 45.27, 8df).

Discussion

The Spring groundlayer community composition showed much less variation between Full Canopy and Light gaps samples than suspected *a priori*. With 17 of the top 18 species common to both samplings (many at virtually identical importances, Table 1), plus a community coefficient value for the two communities of 85.8% similarity, could hardly be expected if the *same* community were sampled twice, with successive samples at different locations. When a coefficient of community was calculated between the Summer groundlayer community of this study and the one taken by Levenson (1973), a value of only 51.1% was obtained. The wider difference was in part due to the almost total absence of Levenson's top dominant species (*Parthenocissus quinquefolia*) from our sample, plus the much greater diversity obtained in Levenson's much larger sample size (0.01 ha).

As was pointed out by Moore and Vankat (1986), many of the Spring groundlayer species have life cycles that are geared to completing flowering and much of their photosynthetic activity prior to canopy closure as the trees reach full leaf. In that sense, the creation of light gaps due to canopy disturbances is not expected to affect spring wildflower patterns appreciably. With the soil profile and leaf litter intact, the biotope of spring wildflowers is probably little changed from full canopied conditions prior to disturbance. In fact some forest wildflower species such as *Claytonia* and *Erythronium* persist for many years in parks and lawns after the original forest canopy is essentially gone, with the soil and leaf litter changed accordingly. Rogers (1982) speculated that death or removal of overstory trees may significantly reduce root competition in the groundlayer, but such effects would be hard to document.

That six growth seasons have elapsed since the light gaps were created have permitted ingrowth and size increases of subcanopy trees which have doubtless partially masked differences in the light regime that occurred immediately following disturbance. Such rapid recovery would favor those groundlayer species (woody and herbaceous) which may be present in a spring sample, yet persist and photosynthesize through more of the growth season.

Late summer groundlayer species exhibited much greater differences between Full Canopy and Light Gaps areas (Table 2). Of the 23 species present in the two communities collectively, only 8 were common to both. During mid-to-late summer the differences in light regime between the two communities is very obvious from a simple woods walk. Moisture relations are likewise modified, though less drastically. These environmental changes plus aggressive invasion by such species as clearweed (*Pilea pumila*) and blackberry (*Rubus allegheniensis*) present serious challenges to regeneration of woody seedlings, especially. Moore and Vankat (1986) found the cover percentages of tree seedlings to decline in older gaps in Heuston Woods in Ohio.

The relatively low diversity of herbaceous species (33 in spring and 23 in summer samplings) may be representative of climax forests as they mature. Brewer's (1980) analysis of the groundlayer species over a 50-year period in Warren Woods in Michigan, pointed to the herbaceous flora becoming progressively more restricted. If this is the case for other beech-maple stands, disturbances such as the damage experienced at Hoot Woods should counteract this downtrend in diversity. We observed a few examples of species increases or invasions into light-gap areas in this study. More long-term studies are sorely needed.

Thompson (1980) examined colonization patterns and diversity differences among herbs in old-growth forests in Illinois in terms of landscape heterogenity created by tip-up mounds and pits following tree falls of varying ages. Our study did not focus on this aspect, as few of our plots centered on those altered landforms. Hoot Woods has relatively uniform topography (being on a gentle east-facing slope with shallow ravines) which would further tend to restrict species diversity.

The low incidence of flowering among groundlayer species (Table 3) may be more of a characteristic of the woods, than of the species. One of the authors (MTJ) has walked this woods during most springs of the past 20 years and has repeatedly commented on the depauperate spring wildflower display. Members of the Hoot family have likewise reminisced about the wildflowers being far fewer now than during their girlhood. The only possible explanation that comes to mind is that the woods was lightly grazed by sheep for a short time during the 1950s. Perhaps the wildflower populations are still recovering from that disturbance and are slowly building vigor necessary before flowering. The botanical literature has a notable paucity of such data as the frequency or consistency of flowering among wildflower populations.

The overwhelming invading woody species into the shrub community in the Light Gaps is blackberry (*Rubus allegheniensis*). In the larger openings it forms near-impenetrable thickets of brambles. Its presence marks the predominant change in the Shrub Community composition (Table 4). Intolerant tree seedlings such as tulip tree and sassafras had minor increases; but composition was similar between the two communities (Table 4). When coefficient of community values were run between this study and that of Donselman (1973), a similarity of 67.4% was obtained. In both studies 20 species contributed to the shrub layer with 14 species in common.

It will be interesting to follow the changes in the shrub layer during the next decade as subcanopy tree ingrowths and size changes create the shade necessary to exclude the blackberry and favor the more typical beech-maple forest shrubs. Data on tree dynamics in Hoot Woods during the past 20 years is being reported elsewhere by Jackson and Abrell, (In Preparation).

Literature Cited

Abrell, D. Brian and Marion T. Jackson. 1977. A decade of change in an old-growth beech-maple forest in Indiana. Amer. Midland Natur. 98: 22-32.

Brewer, Richard. 1980. A half-century of changes in the herb layer of a climax deciduous forest in Michigan. J. Ecol. 68: 823-832.

Donselman, Henry M. 1973. An ecological analysis of the shrub stratum in the beech-maple forest type. M.A. Thesis, Indiana State University, Terre Haute, Indiana. 128 p.

Jackson, Marion T. and D. Brian Abrell. 1977. Volume changes in an old-growth beech-maple forest over a 10-year period. *Proc. Indiana Acad. Sci.* 86: 177-181.

Jackson, M.T. and P.R. Allen. 1967. Use of large scale forest maps for teaching forest sampling methodology. *Proc. Indiana Acad. Sci.* 76: 243-250.

Levenson, James B. 1973. The herbaceous stratum of the beech-maple forest: A community structure analysis. M.A. Thesis, Indiana State University, Terre Haute, Indiana. 134 p.

Moore, Michael R. and John L. Vankat. 1986. Responses of the herb layer to the gap dynamics of a mature beech-maple forest. Amer. Midland Natur. 115: 336-347.

Petty, R.O. and A.A. Lindsey. 1961. Hoot Woods, a remnant of virgin timber in Owen County, Indiana. *Proc. Indiana Acad. Sci.* 71: 320-326.

Riemenschneider, Victor and Thomas D. Blodgett. 1984. Post wind damage survey of herbaceous level in Bendix Woods Nature Preserve, St. Joseph County, Indiana. *Proc. Indiana Acad. Sci.* 93: 199-206.

U.S.D.A 1964. Owen County Indiana Soil Survey Report, Purdue University Agric. Erpt. Station, W. Lafayette, Indiana. 120 p. + maps.

Rogers, Robert S. 1982. Early spring herb communities in mesophytic forests of the Great Lakes Region. Ecology 63: 1050-1063.

Thompson, John N. 1980. Treefalls and colonization patterns of temperate forest herbs. Amer. Midland Natur. 104: 176-184.

Williamson, G.B. 1975. Pattern and seral composition in an old-growth beech-maple forest. Ecology 56: 727-731.

The Fern Genera *Vittaria* and *Trichomanes* in Indiana

George Yatskievych[1]
Department of Biology
Indiana University
Bloomington, Indiana 47405
Michael A. Homoya
Indiana Department of Natural Resources
Indianapolis, Indiana 46204
Donald R. Farrar
Department of Botany
Iowa State University
Ames, Iowa 50011

When Deam's *Flora of Indiana* (4) was first published in 1940, it included 57 species of pteridophytes in 24 genera. Ten years later, Clevenger (2) reported 61 total species, still in 24 genera. Today a taxonomically conservative count would yield ca. 73 species in 26 genera. Two self-evident reasons account for the increased number of pteridophytes now recognized to grow in Indiana. The first is that our understanding of species limits among temperate North American ferns has changed dramatically since the publication of Deam's flora, with an increasingly large number of taxonomic and evolutionary studies on these plants (e.g., 12, 21). In addition, new distributional records have resulted from continuing field work by a number of collectors in the state (e.g., 10, 13). The realization that our knowledge of Indiana's fern flora remains incomplete and inexact for many taxa has prompted this report, which concerns three taxa in two genera newly found in the state in recent years.

Vittaria

The genus *Vittaria* (Vittariaceae) comprises ca. 50 primarily epiphytic tropical species (20), of which *V. lineata* J. Smith, whose range presently extends to northern Florida, was once thought to be the only extratropical member. It is now known that gametophytes of a *Vittaria* species exist independently of the sporophyte generation and are distributed as far north as northern Ohio and southwestern New York (8, 18). These gametophytes were originally thought to belong to the filmy fern genus *Hymenophyllum* (23), but were later assigned to *Vittaria* (22). The biology and biogeography of these plants have since been studied in some detail (5-9), although the distribution and habitat requirements of Indiana populations have previously not been published upon.

The Appalachian *Vittaria* gametophytes, as they are commonly known, were first reported for Indiana from a single locality in Crawford County (11). Two subsequent reports (9, 16) made brief mention of records from Martin and Perry Counties, without citation of localities or vouchers. Specimens from all presently known stations in the state are listed in Table 1.

Plants are found at sites where temperature and edaphic conditions remain relatively constant year-round. Non-calcareous substrate is essential for establishment and growth. Elsewhere, *Vittaria* gametophytes have been found growing on a variety of substrate types, including sandstone, quartzite, schist, gneiss, slate, shale, coal, and rarely wood (7), but in Indiana they have thus far been found associated only with the massive Pennsylvanian and (to a lesser extent) Mississippian-age sandstone outcrops in the Crawford Upland Section of the Shawnee Hills Natural Region (15). In places where continuous outcrops form series of bluffs or cavernous rock-houses, populations are found under moist overhangs where high humidity and stable, cool temperatures prevail. Normally such

Table 1. Specimens documenting the distribution of *Vittaria* and *Trichomanes* in Indiana. Vouchers are accessioned either at the Deam herbarium of Indiana University (IND) or the herbarium of the Department of Botany, Iowa State University (ISC).

Vittaria sp. (gametophytes):

Crawford Co. ca. 1 mi. east of Perry Co. line on State Hwy. 62, 12 July 1969, *Farrar 1263 1264* (ISC), 10 Nov. 1981, *Farrar 81-11-10-2, 81-11-10-3* (ISC), 10 May 1986, *Yatskievych & McCrary 86-50* (IND); 1 mi. west of West Fork on State Hwy. 37, 8 May 1971, *Wagner 71087* (ISC); Yellow Birch Ravine, ca. 1 mi. southeast of Taswell on rd. to Mifflin, 11 Sep. 1983, *Yatskievych & McCrary 83-283* (IND); bluffs southeast of Mifflin and southwest of Otter Creek, 1 May 1976, *Gastony 1102* (IND), 14 Sep. 1982, *Yatskievych & Gastony 82-238* (IND); Hemlock Cliffs, west of Grantsburg, 13 Nov. 1981, *Farrar 81-11-13-1, 81-11-13-2* (ISC), 14 Sep. 1982, *Yatskievych & Gastony 82-237* (IND).

Martin Co. East Fork White River, 4.2 mi. north of Shoals, 11 Nov. 1981, *Farrar 81-11-11-3* (ISC); west bank of East Fork White River, ca. 1 mi. south of Shoals, 16 Jan. 1983, *Yatskievych & McCrary 83-21* (IND); small southern tributary of Plaster Creek, just west of Jackman Hill Rd., ca. 5 mi southwest of Shoals; 14 Oct. 1984, *Yatskievych & McCrary 84-185* (IND).

Perry Co. Penitentiary Rocks, near Mt. Pleasant, 13 Nov. 1981, *Farrar 81-11-13-4, 81-11-13-5* (ISC); Abbot's Hollow, ca. ½ mi. west of Branchville, 17 Oct. 1982, *Yatskievych & McCrary 82-258* (IND.); Rich Cave Hollow, off Jubin Creek, ca. 1½ mi. north of Branchville, 17 Oct. 1982, *Yatskievych & McCrary 82-259* (IND); Rockhouse Hollow, ca. 3 mi. northwest of Derby, 12 Nov. 1986, *Homoya, Guindon, and Springarn 86-11-12-105* (IND).

Trichomanes boschianum (sporophytes):

Crawford Co. Yellow Birch Ravine, 22 May 1977, *Swayne & Swayne 77-Ind-9* (IND).

Martin Co. Plaster Creek watershed, 31 May 1984, *Homoya, Engle, Huffman & Hutchison s.n.* (IND).

Trichomanes sp. (gametophytes):

Crawford Co. ca. 1 mi. E of Perry co. line on State Hwy. 62, 12 July 1969, *Farrar 1265* (ISC).

Martin Co. East Fork White River, ca. 1.3 mi. northeast of Shoals, 2 May 1965, *Farrar 1007, 1008, 1009* (ISC); ca. 5 mi. southeast of Shoals, 50-100 ft. from end of box canyon, 2 May 1965, *Farrar 1010* (IND, ISC), *1011, 1012* (ISC).

Montgomery Co. Shades State Park, small tributary to Sugar Creek, 16 July 1968, *Farrar 1178* (ISC).

Perry Co. State Hwy. 62, 1 mi. west of junction with State Hwy. 145, 10 Nov. 1981, *Farrar 81-11-10-1* (ISC).

localities exhibit at least partial zonation with respect to light intensity, the *Vittaria* gametophytes occupying sites receiving less light than most mosses and liverworts require, and more light than some species of green and blue-green algae.

Appalachian *Vittaria* gametophytes occur in long-lived colonies of various densities and sizes, often discontinuously occupying the uneven contours of their substrate. Individual plants start out as few-celled filaments, but soon grow into irregularly lobed ribbon-like thalli, mainly one cell thick, and enlarging by numerous marginal meristems (Figure 1a). Plants are roughly differentiated into two parts (7). Short basal areas, anchored by hairlike unicellular rhizoids are appressed to and often partially buried in the substrate. Elongate aerial portions are oriented at right angles to the direction of the light. Degree of lobing is variable and depends at least in part on light intensity.

Most populations produce gametangia, although these are not easily observed. Antheridia are normally produced only on young thalli, often while still in the filamentous stage. Archegonia occur amidst rhizoids on the appressed basal lobes of mature plants. Farrar (7) reported three young abortive sporophytes of presumed apogamous origin in a population from Ohio, but sporophyte production has not been observed at any other locality, including those in Indiana. Reproduction is thus accomplished entirely asexually, by fragmentation of existing thalli and by production of filamentous, spindle-shaped gemmae (Figure 1b), the latter formed from specialized gemmiferous cells located along the margins of terminal lobes of mature gametophytes. Each gemmifer normally produces one to several pairs of gemmae, each from two to twelve cells in length. The individual gemmae are easily disarticulated from the gemmifers and are probably dispersed by water, wind, and insects or other small inhabitants of the sites. Irregular gemma for-

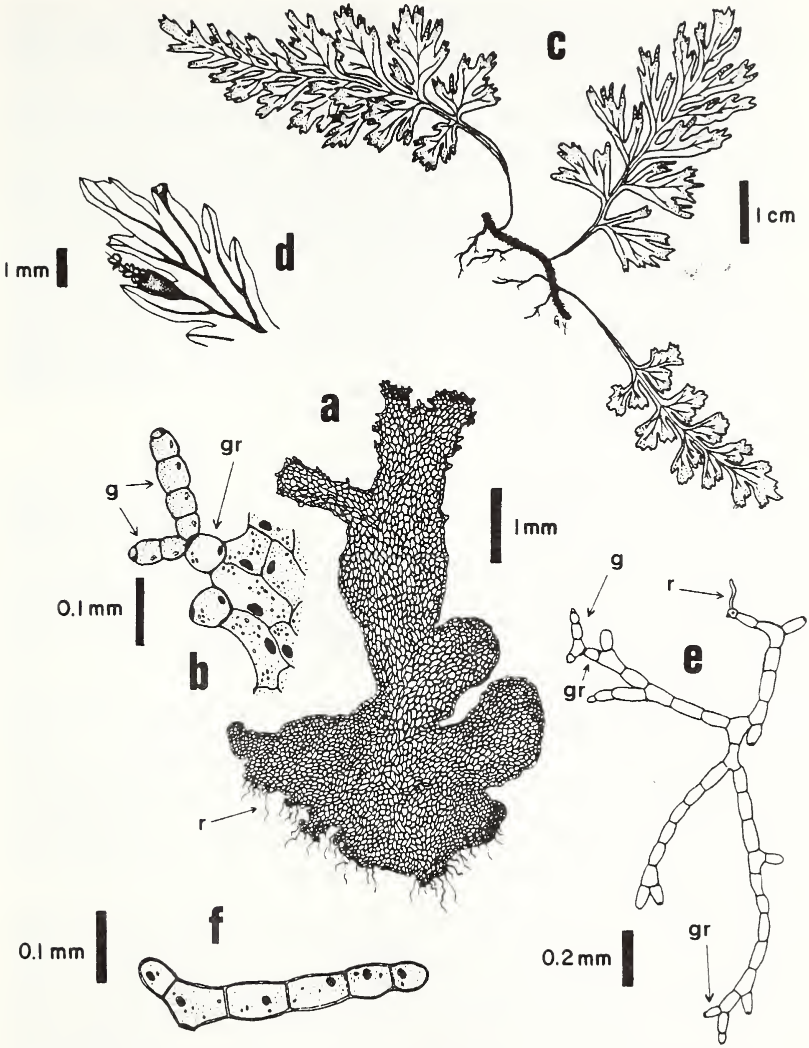


FIGURE 1. a. Independent *Vittaria* sp. gametophyte, b. Detail of terminal lobe of *Vittaria* gametophyte showing two gemmifers, one with a pair of gemmae, c. *Trichomanes boschianum* sporophyte, d. Pinna of *Trichomanes* sporophyte with mature sorus (sporangia on exserted receptacle) and developing sorus, e. Portion of independent *Trichomanes* sp. gametophyte, f. Detached gemma of *Trichomanes* gametophyte. g = gemma, gr = gemmifer, r = rhizoid.

mation involving the production of chains of gemmifers or T-shaped gemmae has also been reported (7), but is rarely observed in field-collected material from Indiana.

The specific identity of the Appalachian gametophyte remains problematic. Determination of fern species in general relies almost entirely on characters of the sporophyte generation and gametophytes of most *Vittaria* species are morphologically essentially indistinguishable. Attempts to generate apogamous sporophytes of Appalachian *Vittaria* from axenic gametophyte cultures show promise, but to date have not successfully yielded mature sporophytes (1).

Wagner and Sharp (22) first suggested that the independently reproducing gametophytes represented a reduced northern variety of the Florida shoestring fern, *V. lineata*. Gastony (11) presented cytological evidence in support of this view, based on a comparison of ploidy levels for single accessions of sporophytes and independent gametophytes. Farrar (7), however, cited minor morphological discrepencies between the gemmae of the Appalachian gametophyte and those of cultured gametophytes of *V. lineata*. More recently, preliminary electrophoretic data from comparisons of enzyme banding patterns have suggested that the independently reproducing gametophytes are a genetically (and therefore taxonomically) distinct taxon from *V. lineata* and three other neotropical shoestring ferns (8). Further experimental work will be necessary to confirm whether the Appalachian *Vittaria* gametophyte represents a reduced temperate offshoot of *V. lineata*, its geographically closest living relative, or whether this odd fern originated from some other, perhaps now otherwise extinct species.

Trichomanes

The primarily tropical filmy fern family Hymenophyllaceae contains ca. 600 species in 2 major genera, *Hymenophyllum* and *Trichomanes*, of approximately equal size (20). Only two extratropical species of *Hymenophyllum* are currently known from North America. Sporophytes of *H. tunbrigense* (L.) J. Smith are known from a single locality in Pickens County, South Carolina, and independent gametophytic colonies of this species occur in an adjoining four county area (5, 8). *Hymenophyllum wrightii* Bosch occurs both as sporophytes and (more commonly) as independent gametophytes in coastal Alaska and British Columbia (19).

In the United States, five species of *Trichomanes* are restrictred to southern Florida (17). Only two species exist as sporophytes further north. The southeastern *T. petersii* A. Gray is found as far north as Arkansas and Tennessee (8), while the more widespread *T. boschianum* Strum ex Bosch has been collected as far north as Ohio and Indiana. Sporophytes of *T. boschianum* have thus far been found at only two Indiana sites, in Crawford and Martin County (13, 14, Table 1). Both populations are small, consisting of few plants showing obvious signs of cold damage. No spore production has been observed at either site.

Populations grow in sheltered, moist (but not wet) sites near the bases of sandstone bluffs and are to be sought in localities adjacent to, but receiving slightly more light, than those previously described for *Vittaria* gametophytes. The plants possess delicate pinnate-pinnatifid fronds with variously lobed to lacerate pinnae (Figure 1c) to 15 mm long (shorter in Indiana plants). Sporangia (when formed) are clustered on hairlike receptacles that are exserted from the marginal, tubular sori (Figure 1d). Superficially, the plants resemble very young sporophytes of *Dryopteris* and *Athyrium*, which are common on sandstone bluffs in southern Indiana, but the filmy fern may be distinguished from these by its slender, hairy (not scaly), creeping rhizomes, winged stipes, and thin, translucent fronds (usually only one cell thick between the veins).

Independent colonies of *Trichomanes* gametophytes occur nearly throughout the range of sporophytes of the genus in the eastern United States and have also been found as far north as central Vermont (9). They largely co-occur with the *Vittaria* gametophytes, but also inhabit somewhat more open sites on the sides of shady boulders. In Indiana, for unknown reasons, the plants are less abundant than the *Vittaria* gametophytes. They have, thus far, been collected in Crawford, Martin, Montgomery, and Perry Counties (Table 1).

Gametophytes of *Trichomanes* form small cottony tufts composed of an intertwined network of branching filaments (Figure 1e). They greatly resemble in appearance a filamentous green alga, but are distinguished morphologically by the presence of short rhizoids, multicellular, spindle-shaped gemmae (Figure 1e, f) similar in appearance to those produced by *Vittaria*, and by their unicellular, flask-shaped gemmifers (Figure 1e) that remain attached to the filaments after the gemmae are shed. Gametangia are rarely present on the independent *Trichomanes* gametophytes.

As with the Appalachian *Vittaria*, the taxonomic identity of the independently reproducing *Trichomanes* gametophytes is problematic. Preliminary data from enzyme electrophoresis (8) suggest that these plants are not conspecific with either *T. boschianum* or *T. petersii*, the two sporophyte-producing filmy fern species whose ranges overlap with those of the sporophyte-less colonies, and whose gametophytes are morphologically indistinguishable from them. Further experimental work will be necessary to address whether the independently reproducing *Trichomanes* gametophytes are a species otherwise extinct, or if they represent a temperate range disjunction for an otherwise tropical species.

Discussion

The genera *Vittaria* and *Trichomanes* have received relatively little attention from Indiana botanists. The independent gametophytes are certainly among the most unusual members of the state's flora, and the sporophytic *T. boschianum* is one of the rarest plant species in the state.

For these sporophytes, severity of winters appears to be the major biogeographic limiting factor. Both Indiana sites are at the climatic extreme, as evidenced by the small size and apparent frost injury of the plants. In contrast, the greatest biogeographic barrier to the spread of both taxa of independent gametophytes appears to be their inefficiency to disperse over long distances. The relatively large (to over 0.5 mm long), filamentous gemmae of these plants are less easily transported by wind currents than the much smaller spores produced by most fern sporophytes, and their thin, unarmored cell walls provide little protection from desiccation, thus making gemmae relatively poor long distance dispersal units. Their slow dispersal rate is evidenced by their spotty occurrence in areas of apparently suitable natural habitats and by the failure of independent gametophytes to colonize altered or recently created habitats such as old quarries and shady roadcuts, even when these lie adjacent to existing populations.

That gemmae of the independent *Trichomanes* gametophytes are somewhat better adapted to dispersal than those of the Appalachian *Vittaria* is attested to by their greater success at recolonization of available habitat north of the Wisconsin and Illinoian glacial boundaries. Since the retreat of the Pleistocene glaciers, *Vittaria* has succeeded in spreading to only two known stations (in northern Ohio and southwestern New York) significantly north of the glacial limits (3, 9, 18). In contrast, independent *Trichomanes* colonies have been reported from a number of stations in previously glaciated areas from Ohio to New Hampshire, as well as the Montgomery County site in Indiana (8, 9).

The distributions of *Vittaria* and *Trichomanes* in Indiana, as circumscribed in this report, should be treated as preliminary, since all suitable localities in the state for these plants have yet to be surveyed. Hopefully the information presented here will stimulate botanists in Indiana to search further for these uncommon ferns, particularly in counties from which they have not previously been reported. Many details of the biology and evolution of the independently reproducing gametophytes have not been studied exhaustively, and provide fertile topics for future research on these interesting and diminutive members of the state's flora.

Literature Cited

1. Caponetti, J.D., M. Whitten, and M.J. Beck. 1982. Axenic culture and induction

of callus and sporophytes of the Appalachian Vittaria gametophytes. Amer. Fern. J. 72:36-40.
2. Clevenger, S. 1950. The distribution of the ferns and fern allies found in Indiana. Butler Univ. Bot. Stud. 10:1-11.
3. Cusick, A.W. 1983. Vittaria gametophytes discovered in a new physiographic province. Amer. Fern. J. 73:33-38.
4. Deam, C.C. 1940. Flora of Indiana. Indiana Dept. of Conservation, Indianapolis. 1236 p.
5. Farrar, D.R. 1967. Gametophytes of four tropical fern genera reproducing independently of their sporophytes in the southern Appalachians. Science 155:1266-1267.
6. Farrar, D.R. 1974. Gemmiferous fern gametophytes—Vittariaceae. Amer. J. Bot. 61:146-155.
7. Farrar, D.R. 1978. Problems in the identity and origin of the Appalachian Vittaria gametophyte, a sporophyteless fern of the eastern United States. Amer. J. Bot. 65:1-12.
8. Farrar, D.R. 1985. Independent fern gametophytes in the wild. Proc. Royal Soc. Edinburgh 86B:361-369.
9. Farrar, D.R., J.C. Parks, and B.W. McAlpin. 1983. The fern genera Vittaria and Trichomanes in the northeastern United States. Rhodora 85:83-92.
10. Gastony, G.J. 1971. Asplenium pinnatifidum X trichomanes—a new record for Indiana. Amer. Fern J. 61:32-34.
11. Gastony, G.J. 1977. Chromosomes of the independently reproducing gametophyte: a new source of taxonomic evidence. Syst. Bot. 2:43-48.
12. Hauke, R.L. 1963. A taxonomic monograph of the genus Equisetum subgenus Hippochaete. Beih. Nova Hedw. 8:1-123 + 9 tab., 22 pl.
13. Homoya, M.A. 1983. Additions to the flora of southern Indiana. Proc. Indiana Acad. Sci. 92:379-382.
14. Homoya, M.A. and D.B. Abrell. 1986. Recent additions to the flora of southern Indiana. Proc. Indiana Acad. Sci. 95:429-432.
15. Homoya, M.A., D.B. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Proc. Indiana Acad. Sci. 94:245-268.
16. Johnson, L.E. 1984. Indiana plant distribution records XXIII. Proc. Indiana Acad. Sci. 93:333.
17. Mickel, J.T. 1979. How to Know the Ferns and Fern Allies. William C. Brown Publ., Dubuque, IA. 229 p.
18. Parks, J.C. and D.R. Farrar. 1984. A first report of the genus Vittaria in New York. Rhodora 86:421-423.
19. Taylor, T.M.C. 1967. Mecodium wrightii in British Columbia and Alaska. Amer. Fern J. 57:1-6.
20. Tryon, R.M. and A.F. Tryon. 1982. Ferns and Allied Plants. Springer-Verlag, New York, NY. 857 p.
21. Wagner, W.H., Jr. 1954. Reticulate evolution in the Appalachian Aspleniums. Evolution 8:103-118.
22. Wagner, W.H., Jr. and A.J. Sharp. 1963. A remarkably reduced vascular plant in the United States. Science 142:1483-1484.
23. Wherry, E.T. 1942. Guide to Eastern Ferns, ed. 2. Science Press, Lancaster, PA. 252 p.

Note

[1] Present address: Missouri Botanical Garden, P.O. Box 299, St. Louis, Missouri, 63166.

A Floristic Survey of the Yellow Birch Ravine Nature Preserve, Crawford County, Indiana

George Yatskievych[1] and Kay McCrary Yatskievych[2]
Department of Biology
Indiana University
Bloomington, Indiana 47405

Introduction

The Crawford Upland Section of the Shawnee Hills Natural Region in unglaciated southern Indiana (4) is characterized by scenic topography, with numerous deep ravines and massive sandstone outcrops. The Yellow Birch Ravine Preserve in Crawford County is one of the finest examples of this natural region in the state. The site has long been of interest to botanists, but no comprehensive floristic inventory has previously been attempted for the area. Our purpose in studying the flora of this preserve was to both survey the vascular plant species presently growing there and examine the floristic changes that may have taken place during the last 40 years of changing vegetation and human impact.

Physical Setting

Yellow Birch Ravine is situated just south and east of the town of Taswell, in Crawford County and occupies portions of sections 19, 20, and 30 in T2S R1W. The 440 acre preserve is bisected by the graded road that runs north from nearby Mifflin to State Highway 64. The outstanding geological feature of the property is a massive series of nearly continuous bluffs formed by outcrops of Pennsylvanian age sandstone bedrock. Limestone outcrops from formations underlying this sandstone are extremely restricted and are found only in a few streambed areas, where water flow has exposed them slightly. Soils on the steep, easily eroded slopes and tops belong to the Wellston-Gilpin-Zanesville-Berks Association of well-drained medium-textured soils that are characteristic of this region (4, 7), while the Haymond silt-loam of the drainage bottoms (7) tends to be somewhat finer and less well drained.

The major vegetation types in the eastern half of the preserve were documented by Lindsey et al. (6) and are identical to those found elsewhere in Yellow Birch Ravine. In general, the bottoms are dominated by a beech-maple forest, while the drier ridgetops are dominated by oak and hickory species (see table 1). Most of the area was lumbered

Table 1. Floristic inventory of Yellow Birch Ravine Nature Preserve. Asterisks indicate county records noted during this study.

Acer rubrum L. var. *rubrum*
Acer saccharum Marsh
**Achillea millefolium* L. ssp. *lanulosum* (Nutt.) Piper
Actaea alba (L.) Mill.
Adiantum pedatum L.
Agalinus tenuifolia (Vahl) Raf. var. *tenuifolia*
Agrimonia parviflora Ait.
Agrimonia pubescens Wallr.
Agrimonia rostellata Wallr.
Agrostis perennans (Walt.) Tuckerm.
**Allium canadense* L.
**Ambrosia artemisiifolia L.*
**Ambrosia bidentata* Michx.
Ambrosia trifida L.
Amelanchier canadensis (L.) Medic.
**Amelanchier laevis* Wieg.

TABLE 1.—Continued

Ampelamus albidus (Nutt.) Britt.
Amphicarpa bracteata (L.) Fern. var. _comosa_ Fern.
Andropogon scoparius Michx. var. _scoparius_
Anemone virginiana L.
Anemonella thalictroides (L.) Spach
*_Antennaria plantaginifolia_ (L.) Richards. var. _ambigens_ (Greene) Cronq.
*_Apios americana_ Medic.
Aplectrum hyemale (Muhl.) Torr.
Aquilegia canadenis L.
Arabis laevigata (Muhl.) Poir.
Aralia racemosa L.
Aralia spinosa L.
*_Arctium minus_ Schkuhr
Arisaema dracontium (L.) Schott
Arisaema triphyllum (L.) Schott var. _triphyllum_
Aristida dichotoma Michx.
Aristida longespica Poir.
Aristida oligantha Michx.
Aronia melanocarpa (Michx.) Ell.
Asarum canadense L. var. _canadense_
Asclepias tuberosa L.
Ascyrum hypericoides L. var. _multicaule_ (Michx.) Fern.
Asimina triloba (L.) Dunal
*_Asparagus officinalis_ L.
Asplenium montanum Willd.
Asplenium pinnatifidum Nutt.
Asplenium platyneuron (L.) Oakes ex D.C. Eaton
Asplenium rhizophyllum L.
Asplenium trichomanes L.
Aster cordifolius L. var. _cordifolius_
Aster pilosus Willd. var. _pilosus_
Athyrium filix-femina (L.) Roth var. _asplenioides_ (Michx.) Farw.
Athyrium pycnocarpon (Spreng.) Tidestrom
Athyrium thelypteroides (Michx.) Desv.
Aureolaria flava (L.) Farw. var. _macrantha_ Pennell
*_Barbarea vulgaris_ R. Br. var. _arcuata_ (Opiz) Fries
*_Bartonia virginica_ (L.) BSP.
Betula lutea Michx. f.
Blephilia ciliata (L.) Benth.
Blephilia hirsuta (Pursh) Benth.
Boehmeria cylindrica (L.) Sw.
Botrychium dissectum Spreng. f. _obliquum_ (Muhl.) Clute
Botrychium virginianum
*_Brachyletrum erectum_ (Schreb.) Beauv.
Bromus purgans L.
Bulbostylis capillaris (L.) Clarke
Cacalia atriplicifolia L.
Campanula americana L.
*_Campsis radicans_ (L.) Seem.
*_Capsella bursa-pastoris_ (L.) Medic.
Cardamine parviflora L. var. _arenicola_ (Britt.) Schulz
Cardamine pensylvanica Muhl.
Carex amphibola Steud.
*_Carex cephalophora_ Muhl.
Carex communis Baileya
Carex complanata Torr. & Hook.
Carex digitalis Willd.
Carex frankii Kunth
Carex glaucodea Tuckerm.
Carex gracillima Schw.
Carex hirtifolia Mack.
Carex laxiculmis Schw.

TABLE 1.—Continued

---

*_Carex laxiflora_ Lam. var. _blanda_ (Dewey) Boott
Carex laxiflora Lam. var. _latifolia_ Boott
Carex laxiflora Lam. var. _laxiflora_
Carex lurida Wahl
Carex nigromarginata Schw. var. _muhlenbergii_ (A. Gray) Gleason
Carex normalis Mack.
Carex oligocarpa Schk.
Carex plantaginea Lam.
*_Carex rosea_ Schkuhr
Carex sparganioides Muhl.
Carex squarrosa L.
*_Carex torta_ Boott
Carex virescens Muhl.
Carex vulpinoidea Michx.
Carex willdenowii Schkuhr
Carpinus caroliniana Walt.
Carya cordiformis (Wang.) K. Koch
Carya glabra (Mill.) Sweet
Carya ovata (Mill.) K. Koch
Cassia fasciculata Michx.
Cassia marilandica L.
Cassia nictitans L. var. _nictitans_
Caulophyllum thalictroides (L.) Michx.
Cercis canadensis L.
*_Chelone glabra_ L.
*_Chenopodium album_ L.
Cinna arundinacea L.
Circaea quadrisulcata (Maxim.) Franch. & Sav. var. _canadensis_ (L.) Hara
Cirsium altissium (L.) Spreng.
*_Cirsium discolor_ (Muhl.) Spreng.
*_Claytonia virginica_ L.
Collinsonia canadensis L.
Conopholis americana (L.) Wallr.
Conyza canadensis (L.) Cronq.
Corallorhiza wisteriana Conrad
Coreopsis tripteris L.
Cornus florida L.
*_Coronilla varia_ L.
Corydalis flavula (Raf.) DC.
Corylus americana Walt.
Croton monanthogynous Michx.
Cryptotaenia canadensis (L.) DC.
*_Cuscuta gronovii_ Willd.
Cynoglossum virginianum L.
Cyperus flavescens L.
Cyperus strigosus L.
Cypripedium calceolus L. var. _pubescens_ (Willd.) Correll
Cystopteris bulbifera (L.) Bernh.
Cystopteris protrusa (Weath.) Blasdell
Danthonia spicata (L.) Beauv.
Daucus carota L.
Dennstaedtia punctilobula (Michx.) Moore
Dentaria heterophylla Nutt.
Dentaria laciniata Muhl. ex Willd.
Desmodium ciliare (Muhl.) DC.
Desmodium glutinosum (Muhl.) Wood
Desmodium nudiflorus (L.) DC.
Desmodium pauciflorus (Nutt.) DC.
*_Desmodium rigidum_ (Ell.) DC.
Desmodium rotundifolium DC.
Dicentra canadensis (Goldie) Walp.
Dicentra cucullaria (L.) Bernh.

TABLE 1.—Continued

Digitaria ischaemum (Schreb.) Muhl.
Diodia teres Walt.
Dioscorea quaternata (Walt.) Gmel. var. _quaternata_
Diospyros virginiana L. var. _virginiana_
Dodecatheon meadia L.
Dryopteris intermedia (Muhl. ex Willd.) A. Gray
Dryopteris marginalis (L.) A. Gray
Echinochloa microstachya (Weig.) Rydb.
Elephantopus carolinianus Willd.
Epifagus virginiana (L.) Bart.
*_Epilobium coloratum_ Biehler
*_Equisetum arvense_ L.
Eragrostis spectabilis (Pursh) Steud.
*_Erianthus alopecuroides_ (L.) Ell.
Erigenia bulbosa (Michx.) Nutt.
Erigeron annuus L.
Erigeron philadelphicus L.
Erigeron strigosus Muhl. var. _strigosus_
Erythronium americanum Ker.
Euonymus atropurpureus L.
Euonymus obovatus Nutt.
*_Eupatorium altissimum_ L.
Eupatorium coelestinum L.
*_Eupatorium hyssopifolium_ L. var. _hyssopifolium_
Eupatorium perfoliatum L.
Eupatorium purpureum L.
Eupatorium rugosum Houtt.
Eupatorium serotinum Michx.
Eupatorium sessilifolium L.
Euphorbia corollata L.
*_Euphorbia dentata_ Michx.
Euphorbia preslii Guss.
Fagus grandifolia var. _grandifolia_
*_Festuca elatior_ L.
Festuca obtusa Biehler
Fraxinus americana L.
Fraxinus pensylvanica Marsh var. _subintegerrima_ (Vahl) Fern.
Galactia volubilis (L.) Britt. var. _mississippiensis_ Vail
Galium aparine L. var. _aparine_
Galium circaezans Michx.
Galium concinnum Torr. & Gray
Galium pilosum Ait. var. _pilosum_
Gaylussacia baccata (Wang.) K. Koch
Geranium carolinianum L. var. _carolinianum_
Geranium maculatum L.
Geum canadense Jacq.
Geum vernum (Raf.) Torr. & Gray
*_Glecoma hederacea_ L.
Gnaphalium obtusifolium L. var. _obtusifolium_
Gnaphalium purpureum L. var. _purpureum_
Goodyera pubescens (Willd.) R. Br.
Hamamelis virginiana L.
Helenium autumnale L. var. _autumnale_
Helianthus divaricatus L.
Helianthus microcephalus Torr. & Gray
Heliopsis helianthoides (L.) Sweet
Hepatica acutiloba DC.
Heuchera americana L. var. _brevipetala_ R. B. & L.
Heuchera parviflora Bartl. var. _rugelii_ (Shuttlew.) R. B. & L.
Hieracium gronovii L.
Hieracium paniculatum L.
Houstonia purpurea L. var. _purpurea_

TABLE 1.—Continued

Hybanthus concolor (Forst.) Spreng.
Hydrangea arborescens L. var. _arborescens_
*_Hydrastis canadensis_ L.
Hydrophyllum macrophyllum Nutt.
Hypericum drummondii (Grev. & Hook.) Torr. & Gray
Hypericum gentianoides (L.) BSP.
Hypericum mutilum L. var. _parviflorum_ (Willd.) Fern.
Hypericum punctatum Lam.
Hystrix patula Moench
Impatiens biflora Walt.
Impatiens pallida Nutt.
Iris cristata Ait.
Isopyrum biternatum (Raf.) Torr. & Gray
Jeffersonia diphylla (L.) Pers.
*_Juglans nigra_ L.
Juncus biflorus Ell.
Juncus effusus L. var. _solutus_ Fern. & Wieg.
Juncus tenuis Willd.
Juniperus virginiana L. var. _crebra_ Fern.
Kalmia latifolia L.
Krigia biflora (Walt.) Blake
Lactuca floridana (L.) Gaertn. var. _villosa_ (Jacq.) Cronq.
*_Lamium purpureum_ L.
Laportea canadensis (L.) Wedd.
Lechea tenuifolia Michx.
Leersia oryzoides (L.) Sw.
Leersia virginica Willd.
*_Lepidium campestre_ (L.) R. Br.
Lespedeza cuneata (Dumont) G. Don
Lespedeza hirta (L.) Hornem.
Lespedeza intermedia (S. Wats.) Britt.
Lespedeza stipulacea Maxim.
Lespedeza striata (Thunb.) Hook. & Arn.
Lespedeza violacea (L.) Pers.
Lindera benzoin (L.) Blume
Linum virginicum L.
Liriodendron tulipifera L.
Lobelia inflata L.
Lobelia puberula Michx.
Lobelia spicata Lam. var. _spicata_
Lobelia syphilitica L. var. _syphilitica_
Lonicera japonica Thunb.
Ludwigia alternifolia L.
Luzula campestris (L.) DC. var. _echinata_ (Small) Fern. & Wieg.
Lycopodium dendroideum Michx.
Lycopodium digitatum Dillen. ex A. Braun
Lycopodium porophilum Lloyd & Underw.
*_Lycopus americanus_ Muhl.
Lycopus virginicus L.
Lysimachia quadrifolia Sims.
*_Medeola virginica_ L.
*_Medicago lupulina_ L.
Melica mutica Walt.
Melilotus alba Desr.
Melilotus officinalis (L.) Desr.
Mentha piperata L.
*_Mimulus ringens_ L.
Mitchella repens L.
Mitella diphylla L.
Monarda fistulosa L. var. _fistulosa_
Monotropa uniflora L.
*_Morus alba_ L.

TABLE 1.—Continued

Muhlenbergia sobolifera (Muhl.) Trin.
Muhlenbergia sylvatica Torr.
Nyssa sylvatica Marsh
**Obolaria virginica* L.
Oenothera biennis L. var. *biennis*
Onoclea sensibilis L.
Orchis spectabilis L.
Ornithogalum umbellatum L.
Osmorhiza claytonii (Michx.) Clarke
Osmunda cinnamomea L.
Ostrya virginiana (Mill.) K. Koch
Oxalis violacea L.
Panax quinquefolium L.
Panicum anceps Michx.
Panicum boscii Poir.
Panicum commutatum Schult. var. *commutatum*
Panicum dichotomum L.
Panicum flexile (Gatt.) Scribn.
Panicum lanuginosum Ell. var. *fasciculatum* (Torr.) Fern.
Panicum laxiflorum Lam.
Panicum polyanthes Schult.
Parietaria pensylvanica Muhl.
Paronychia canadensis (L.) Wood
Parthenocissus quinquefolia (L.) Planch.
Passiflora lutea L.
**Pedicularis canadensis* L.
Penthorum sedoides L.
**Perilla frutescens* (L.) Britt.
Phacelia bipinnatifida Michx.
Phlox divaricata L. var. *divaricata*
Physostegia virginiana (L.) Benth.
Pilea pumila (L.) A. Gray
Plantago rugelii Decne.
**Platanthera peramoena* (A. Gray) A. Gray
Platanus occidentalis L.
Poa compressa L.
Poa pratensis L.
Poa sylvestris A. Gray
Podophyllum peltatum L.
Polemonium reptans L. var. *reptans*
**Polygonatum biflorum* (Walt.) Ell.
**Polygonum arifolium* L.
Polygonum aviculare L.
Polygonum erectum L.
Polygonum hydropiperoides Michx. var. *hydropiperoides*
**Polygonum punctatum* Ell.
Polygonum sagittatum L.
Polygonum virginianum L.
Polypodium polypodioides (L.) Watt var. *michauxianum* Weath.
Polypodium virginianum L.
Polystichum acrostichoides (Michx.) Schott
Populus grandidentata Michx.
Potentilla simplex Michx.
Prenanthes altissima L. var. *cinnamomea* Fern.
Prunella vulgaris L. var. *lanceolata* (Barton) Fern.
Prunus serotina Ehrh.
Pteridium aquilinum (L.) Kuhn var. *pseudocaudatum* (Clute) Heller
Pycnanthemum flexuosum (Walt.) BSP.
Pycnanthemum pycnanthemoides (Leavenw.) Fern. var. *pycnanthemoides*
Quamoclit coccinea (L.) Moench
Quercus alba L.
Quercus coccinea Moench

TABLE 1.—Continued

Quercus muhlenbergii Engelm.
Quercus rubra L.
Quercus stellata Wang.
Quercus velutina Lam.
Ranunculus hispidus Michx. var. *hispidus*
Ranunculus recurvatus Poir.
Rhus copallina L.
Rhus glabra L.
Rhus radicans L. var. *radicans*
**Rhynchospora capitellata* (Michx.) Vahl
Rosa carolina L.
**Rosa multiflora* Thunb.
**Rubus enslenii* Tratt.
Rubus occidentalis L.
Rudbeckia hirta L. var. *hirta*
Rudbeckia triloba L. var. *triloba*
Rumex crispus L.
Sabatia angularis (L.) Pursh
**Sagittaria brevirostra* Mack. & Bush
Salix nigra L.
Salix sericea Marsh
Salvia lyrata L.
Samolus floribundus HBK.
Sanguinaria canadensis L.
Sanicula canadensis L.
Sanicula gregaria Bickn.
Sassafras albidum (Nutt.) Nees
Scirpus atrovirens Willd. var. *atrovirens*
Scirpus cyperinus (L.) Kunth
Scirpus lineatus Michx.
**Scirpus polyphyllus* Vahl
**Scrophularia marilandica* L.
Scutellaria incana Biehler var. *incana*
Scutellaria lateriflora L.
Sedum ternatum Michx.
Selaginella apoda (L.) Spring
Senecio aureus L.
Senecio glabellus Poir.
Setaria geniculata (Lam.) Beauv.
Silene antirrhina L.
**Silene stellata* (L.) Ait. f. var. *scabrella* (Nieuwl.) Palmer & Stey.
Silene virginica L.
Smilacina racemosa (L.) Desf.
Smilax glauca Walt. var. *glauca*
Smilax hispida Muhl.
Solidago bicolor L.
Solidago caesia L.
Solidago canadensis (L.)
Solidago erecta Pursh
Solidago flexicaulis L.
Solidago graminifolia (L.) Salisb. var. *graminifolia*
Solidago nemoralis Ait. var. *nemoralis*
Solidago sphacelata Raf.
Sorghum halepense (L.) Pers.
Sphenopholis nitida (Biehler) Scribn.
Spiranthes cernua (L.) Rich. var. *cernua*
Spiranthes gracilis (Bigel.) BEck
Spiranthes ovalis (Lindl.
Spiranthes tuberosa Raf.
Staphylea trifolia L.
**Stellaria media* (L.) Cyrill.
Stellaria pubera Michx.

TABLE 1.—Continued

Strophostyles umbellata (Muhl.) Britt.
**Taraxacum officinale* Weber
Tephrosia virginiana (L.) Pers.
Thaspium trifoliatum (L.) A. Gray var. *flavum* Blake
Thelypteris hexagonoptera (Michx.) Weath.
Tilia americana L.
Tipularia discolor (Pursh) Nutt.
Tradescantia subaspera Ker. var. *subaspera*
Tradescantia virginiana L.
Trichomanes boschianum Sturm ex Bosch
**Trifolium repens* L.
Trillium gleasonii Fern.
Trillium recurvatum Beck
Triodia flava (L.) Smyth.
Tsuga canadensis (L.) Carr.
**Typha latifolia* L.
Ulmus americana L.
Ulmus rubra Muhl.
Uvularia grandiflora Sm.
Vaccineum stamineum L.
Vaccinium vacillans Kalm ex Torr.
**Valeriana pauciflora* Michx.
Verbascum thapsus L.
Verbena urticifolia L. var. *urticifolia*
Verbesina alternifolia (L.) Britt.
Vernonia altissima Nutt.
Veronica peregrina L. var. *peregrina*
Viburnum acerifolium L.
**Viola eriocarpa* Schw.
**Viola missouriensis* Greene
Viola striata Ait.
Viola triloba Schw. var. *triloba*
Vitis aestivalis Michx. var. *argentifolia* (Munson) Fern.
Vittaria sp.
Woodsia obtusa (Spreng.) Torr.

at various times prior to the establishment of the nature preserve and few large trees remain. Shrubby second-growth thickets occupy portions of the bottoms in the western half, with a substantial tangle of Japanese honeysuckle (*Lonicera japonica*) dominant in one area.

The preserve also supports a number of old fields in various stages of succession, primarily on ridgetops that were previously lumbered and/or farmed. These are dominated by little bluestem (*Andropogon scoparius* var. *scoparius*) and curly oat grass (*Danthonia spicata*), with scattered red cedars (*Juniperus virginiana* var. *crebra*), flowering dogwoods (*Cornus florida*), and blueberries (*Vaccinium* spp.), among others. A small hillside seepage area, dominated by cattail (*Typha latifolia*) and silky willow (*Salix sericea*), occupies a portion of one old field, while other fields contain areas that are somewhat eroded, mainly with a thin covering of lichens and annuals.

Much of the floristic diversity of the preserve can be attributed to the relatively large variety of microhabitats present. Various degrees and directions of exposure are found along the bluffs, at both wetter and drier sites. Stream flow varies from permanent to highly intermittent, at sites with bedrock, gravelly sand, and fine silt substrates. Each of these smaller habitats contains herbaceous species not found elsewhere in the preserve. In addition, degree of erosion and successional status of the various old fields have allowed colonization by a large number of weedy and nonweedy plant species.

Other disturbed habitats have also affected the floristic diversity of the preserve. Three small mines (inactive for some time) provide sheltered vertical habitat and are being recolonized by both vascular and nonvascular species. The shale and limestone spoils from one of these are a novel substrate for the area. Of greater importance is an inactive sandstone quarry (and the roadbed leading to it) on a ridgetop in the eastern half of the preserve. Soil cover over the sandstone in this formerly bare area is thin to nonexistent in places, creating an edaphically harsh environment that most of the plants found elsewhere in the preserve are unable to colonize. Several species not found elsewhere in the area have, however, been successful in utilizing portions of this habitat, notably mountain laurel (*Kalmia latifolia*) and small-flowered ladies' tresses orchid (*Spiranthes tuberosa*), considered respectively rare and threatened in the state (1).

History of Botanical Study

The series of ravines comprising the present preserve have along been known to Indiana botanists, with collections accessioned at the Deam Herbarium of Indiana University (IND) dating from the end of the last century. They were a favorite Crawford County collecting site for Deam, who made 11 trips there from 1911 to 1945. Other well known Indiana botanists, including Potzger and Friesner, also collected in the area during this time. Lindsey and his associates completed vegetational and floristic work in 1967, during their natural areas survey of the state. It was at this time that the name Yellow Birch Ravine first came into usage to commemorate the only southern Indiana station for yellow birch (*Betula lutea*), previous collectors having referred to the area simply as "ravines 1 miles east of Taswell". Prior to and during the acquisition of the land parcels comprising the present preserve, personnel of the Indiana Department of Natural Resources searched for uncommon plant species and assembled a preliminary plant list for the property. Recent collections at IND from the preserve include those of Aldrich, Homoya, Huffman, Post, and Ritter, among others.

Methods

We took several preliminary trips to the preserve in 1983 (September, November) and 1985 (April), followed by approximately triweekly forays during 1986 (March to September). Species lists were compiled in the field during all visits and, when necessary for identification, pressed specimens were taken for later herbarium study. These vouchers are accessioned at IND. Many species were also photographed in the field. Potential county records were checked against the distribution records in Deam's flora (2), subsequent records reported in numerous volumes of the *Proceedings of the Indiana Academy of Science*, the computerized *Floristic Atlas for Indiana* (5), and specimens already accessioned at IND. Nomenclature follows that of Gleason and Cronquist (3), updated where necessary.

Two lists served as starting points for our survey. A preserve plant list was generously provided by the Division of Nature Preserves, consisting of 172 species noted during numerous visits by Indiana Department of Natural Resources personnel over the last few decades. A second list of some 132 specimens (93 taxa) was compiled from the collection books of Charles Deam housed at IND. From the latter list it was possible to assess qualitatively what levels of species turnover had occurred in the preserve since the time of Deam's last visit, in 1945.

Results and Discussion

The combined species inventory for the Yellow Birch Ravine Preserve, including data from our study and previous lists, is detailed in table 1. Of the 423 taxa listed, 380 were verified during our field work. An additional nine species present on the state's preserve plant list were excluded, as these are probably taxa misdetermined by previous workers. The 43 other species noted by earlier workers and not rediscovered by us probably represent cases of both extirpations in the area due to natural or human-mediated causes and oversights on our part of localized populations.

The preserve supports populations of eleven species presently on the state register of endangered, threatened, and rare plant species (1). These are: the state endangered mountain spleenwort (*Asplenium montanum*), southern dewberry (*Rubus enslenii*), filmy fern (*Trichomanes boschianum*), and ground pine (*Lycopodium dendroideum*); the state threatened Mississippi milk pea (*Galactia volubilis* var. *mississippiensis*), late alum root (*Heuchera parviflora* var. *rugelii*), and two ladies' tresses orchids (*Spiranthes ovalis*, *S. tuberosa*); and the state rare hay-scented fern (*Dennstaedtia punctilobula*), mountain laurel (*Kalmia latifolia*), and Lloyd's clubmoss (*Lycopodium porophilum*). In addition several other species uncommon in southern Indiana are present (see table 1).

Species recruitment during the last forty years has been appreciable, particularly in the relatively recently disturbed habitats adjacent to the two old road beds that traverse the property, and at the old quarry site. Species such as toothed ragweed (*Ambrosia bidentata*), yellow bartonia (*Bartonia virginica*), purple fringeless orchid (*Platanthera peramoena*), small-headed beaked rush (*Rhynchospora capitellata*), short-beaked arrowhead (*Sagittaria brevirostra*), and small-flowered ladies' tresses orchid (*Spiranthes tuberosa*), among others, have probably all colonized the preserve since the time of Deam's collections and are all restricted to these relatively recently altered sites.

Species attrition in the preserve is less easily documented. Some distinctive and easily recognizable plants present on the state's preserve plant list were not relocated during our survey, such as black-fruited chokeberry (*Aronia melanocarpa*), large yellow ladies' slipper orchid (*Cypripedium calceolus* var. *pubescens*), and American elm (*Ulmus americanus*), and probably represent localized extinctions. In fact, excluding the 9 unlikely taxa mentioned previously, we failed to relocate 24 (14%) of the 172 species on the preserve plant list. Of these 24, however, 8 are species of the large and taxonomically difficult genus *Carex* (sedges) for which no previously collected vouchers from the preserve could be located and whose presence in Yellow Birch Ravine is problematic.

Of the 93 taxa collected by Deam, we were unable to relocate 16 (17%) during our field work. Some of these, such as the bracken fern variety *Pteridium aquilinum* var. *pseudocaudatum*, which is a large and easily recognized fern that is uncommon in Indiana, have undoubtedly become extirpated since the time of Deam's collections. This is particularly true of the eight species from the above list that Deam collected in open ridgetop areas (often listed as adjacent to cleared areas or along cultivated fields), where the greatest rate of species turnover in the preserve has probably taken place. For unrelocated taxa both from Deam's list and from the state's preserve plant list, one cannot, however, rule out the possibility that we simply overlooked highly localized or otherwise uncommon plants still present in the preserve. The period of time available for our fieldwork was too short to exhaustively survey every square meter of the area. We nevertheless feel confident that the floristic inventory presented in table 1 is reasonably complete for both common and rare plant species that occur in Yellow Birch Ravine today.

This inventory contains more than twice the number of plants previously reported for the area, and includes 63 Crawford County records (see table 1). Slightly over one half of the 666 vascular plant species records for Crawford County contained in the computerized floristic atlas for the state (5) are present in the preserve. These figures indicate that both the county and the preserve have not been well inventoried in the past and suggest that the percent of unrelocated species, calculated by comparing Deam's and the state's plant lists with our field notes, may be biased because of the relatively large number of common taxa not recorded by previous investigators.

Our study has documented that Yellow Birch Ravine has retained a high level of plant species diversity in spite of the significant vegetational changes during this century caused by mining, lumbering, and farming, as well as natural successional processes. While the apparent extinction of some species and the invasion of other native and non-native taxa can be documented, the overall floristic complement of the property has probably remained fairly constant. Thus, in spite of relatively high levels of human impact and a resultant relatively poor forest rating by Lindsey et al. (6), the preserve remains an outstanding physical and botanical example of the Crawford Upland Division of the Shawnee Hills Natural Region as seen in southern Indiana.

Acknowledgments

The Division of Nature Preserves of the Indiana Department of Natural Resources is to be commended for its conservation and management of the Yellow Birch Ravine Nature Preserve, and in particular John Bacone and Michael Homoya deserve thanks for assistance with questions about the area and the issuance of a collecting permit in support of our study. Lewis Johnson of the Deam Herbarium rendered inestimable assistance with determinations of Gramineae and allowed us to examine the collection books of Charles Deam, for which we are most grateful. We would also like to express our thanks to Dr. Paul Rothrock of Taylor University, for information on his field observations of *Carex* species in the area.

Literature Cited

1. Aldrich, J.R. and J.A. Bacone. 1986. List of extirpated, endangered, threatened and rare vascular plants in Indiana: an update. Proc. Indiana Acad. Sci. 95:413-419.
2. Deam, C.C. 1940. Flora of Indiana. Indiana Department of Conservation, Indianapolis, IN. 1236 p.
3. Gleason, H.A. and A. Cronquist. 1963. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. D. Van Nostrand Co., New York, NY. 810 p.
4. Homoya, M.A., D.B. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Proc. Indiana Acad. Sci. 94:245-268.
5. Keller, C., T. Crovello, and K. Guild. 1984. Floristic Atlas for Indiana. Unpublished microcomputer database program (for description, see C. Keller. 1986. The computerization of regional floristic data. Proc. Indiana Acad. Sci. 95:412.
6. Lindsey, A.A., D.V. Schmelz, and S.A. Nichols. 1969. Natural Areas in Indiana and Their Preservation. Indiana Natural Areas Survey, Purdue University, Lafayette, IN. 594 p.
7. Wingard, R.C., Jr. 1975. Soil Survey of Crawford County, Indiana. U.S.D.A. Soil Conservation Service, Washington, D.C. 60 p.

Note

[1,2] Present address: Missouri Botanical Garden, P.O. Box 299, St. Louis, Missouri 63166.

PSYCHOLOGY

Chair: Barbara Kane
Department of Educational and School Psychology
Indiana State University
Terre Haute, Indiana 47809 (812) 237-2882

Chair-Elect: Michael R. Stevenson
Department of Psychological Science
Ball State University
Muncie, Indiana 47305 (317) 285-1716

ABSTRACTS

Changing Attitudes toward Homosexuality. Leah J. Freeland and Michael R. Stevenson, Department of Psychological Sciences, Ball State University, Muncie, Indiana 47306.——This study examined the effectiveness of a filmstrip on homosexuality and a live presentation by Ball State Gay Alliance in changing attitudes toward homosexuality. Participants were 58 male and 113 female students enrolled in one of three Introduction to Psychology classes. All were given the Kite Attitude Toward Homosexuality Scale and a demographic questionnaire during their usual class times. One week later a filmstrip on homosexuality was shown to one class and the Gay Alliance gave a presentation to a second class. The third class was given no additional information on homosexuality. Two weeks later the measures were readministered. A 2 × 3 analysis of covariance revealed no significant differences between groups or by gender. However, regression analysis indicated participants who had read about homosexuality were more likely to change their attitudes. Further analyses showed that those with positive attitudes toward homosexuality had a friend who was homosexual, were female and/or had a relative who was homosexual. Results were discussed in relation to extant literature, recent concern about AIDS and methodological difficulties in this research.

A Note on Dangers in Hypnosis. Walter Hartmann, Department of Behavioral Sciences, Purdue University Calumet, Hammond, Indiana 46323.——Possible ill effects arising from hypnosis have been widely discussed, warned against or dismissed. Examples are cited from a wide range of investigators and observers over the last hundred years. On the one hand, they report physiological difficulties, neurotic complexes, psychosis, antisocial behavior, obsessive dependency (largely from clinical rather than experimental settings); on the other hand, such problems are considered negligible or non-existent.

Discussion, with examples and further quotations, leads to the following.

There are no dangers in hypnosis as such. Contradictions and confusions are resolved by understanding that the hypnotic relationship is no more and no less than any human interaction. Thus, dangers are a function of the way the hypnotic situation, like any human encounter, is structured, carried on, and aimed.

Later Immune Reactivity as a Function of Experience before Weaning and Strain of Mouse: A Preliminary Investigation. Samuel B. Schnitzer, Department of Psychology, Indiana State University and Roy W. Geib, THCME, Indiana University School of Medicine, Terre Haute, Indiana 47809.——Immune reactivity was measured in two litters each of A/J and DBA/2J and one litter of C57B1/6J inbred mice, strains differing in emotionality from high to low. One litter of the former strains and all of the last-named were "handled" daily from birth until 21 days old. "Handling" consisted of being contained in a box, separated from the mother, for 3 min. At approximately 47 days of age, all mice were sensitized to sheep erythrocytes (SRBC) by iv injection of SRBC. One week later, about half the animals of each strain and handling condition were subjected to an open field situation for 3 min. In all mice, thickness of the right hind foot was then measured, after which a challenge dose of SRBC was injected into the foot. Foot thickness was again measured 24 and 48 hrs after challenge. At 48 hrs, while not differing from each other, thickness had increased significantly more in mice of the C57 and DBA strains than in the A animals. Handled mice also showed significantly greater increases in foot thickness than did nonhandled animals. Open field experience seems not to have contributed differentially to increases in thickness. Some other findings were suggestive.

Self-ratings of Masculinity and Femininity by High School Students

Kathryn N. Black, Catherine M. Roe and Julie A. Kable
Department of Psychological Sciences
Purdue University
West Lafayette, Indiana 47907

Introduction

One of the first categories learned by children is that of gender. Not only do we very early learn that we are either a boy or girl but we also learn that others are either male or female. The continued importance of this category can be seen by noting that whenever we see or meet someone the first thing that we note about them is whether they are male or female. Gender, and gender identity—feeling that we are either male or female—are both an all or none phenomenon. This is not necessarily true for other aspects of sex role. For example, we use the terms "masculine" and "feminine" in ways that indicate that these can vary along a continuum, that we can be more or less masculine, and more or less feminine. Originally, research and theorizing assumed that the healthy male would be masculine and the healthy female feminine. Masculinity and femininity were assumed to be at opposite ends of a continuum and it was thought that if one became more feminine that necessarily meant that you were less masculine.

Constantinople (4) has suggested that masculinity and femininity should be considered as two separate dimensions. Further, it has been suggested by Bem (2) that the healthy personality is one that has both desirable masculine characteristics and desirable feminine characteristics. Bem (1), Spence (6), and others have developed a number of paper and pencil inventories asking about the person's self-perception of a variety of personality characteristics that include traits that have been stereotyped as masculine or feminine. A great number of studies have found that there are indeed a large number of college students and other persons who will report themselves to be what has been called androgynous. That is, they have a high amount both of some traits considered ideal for males and some traits considered ideal for females.

Are these tests in fact good measures of masculinity and femininity? Do many people now conceive themselves to be a blend of masculine and feminine? These are examples of questions that are part of an ongoing dialogue in the sex-role literature. The present paper reports on part of a research program concerned with what is meant by masculinity and femininity.

The present paper reports on data from high school students—a sample that is both younger and more representative of the general population. The question we will be concerned with has to do with the extent to which these students see themselves as masculine and feminine.

Methods

Subjects

Four-hundred and ninety-three high school students were given the questionnaire. Data were analyzed for 468 of the subjects who were single, childless, and white. That is, twenty-five questionnaires were eliminated. This included three people who were married, four who were non-white, and three others who were parents; 9 subjects were eliminated because they did not fill out a major part of the questionnaire. In addition, six subjects were eliminated because of a joking response on some part of the questionnaire (e.g., one 17-year-old claimed to be the father of 12 children). Of these 468 subjects (90 males and 105 females) or 195 in total, attended a private, Catholic high school located in Evansville, Indiana, and 273 subjects (131 males and 142 females) were gathered from a Monroe, Indiana, public high school. Subjects ranged in age from 14 to 19 with a mean age of 16.05. The mean age of the sexes did not differ statistically.

Procedure

One of the two female experimenters administered the questionnaires. Both were undergraduate honors majors in psychology and were doing this as a senior research project. Subjects were informed both verbally and in writing that the project concerned masculinity and femininity, and that their participation was anonymous and voluntary. The private high school students were given the questionnaire during their study hall period, and students from the public high school were given the questionnaire while attending various social science classes.

Subjects were given one of six forms of the questionnaire which resulted from variations in either one of two major parts of the questionnaire.

Part I asked the subjects to rate the degree to which they felt feminine or masculine using ratings ranging from 1 (never or almost never) to 7 (always or almost always). These are identical to two items found on the Bem Sex Role Inventory. Half of the orders listed masculinity first and half listed femininity first.

The second part of the questionnaire asked the subjects one of three questions: what they thought made themselves masculine and feminine; what made a male masculine and feminine; or what made a female masculine or feminine. The listing of masculinity and femininity was also counterbalanced. Analyses of these responses will be reported in a separate paper.

All subjects were given the same questions in the third part of the questionnaire. They were asked to report the amount of education completed by their mother and their father, and the amount of education they themselves expected to obtain. Subjects also listed their mother's occupation, their father's occupation, and their own expected occupation. Finally, subjects were asked to report their race and religion.

Results

Table I shows the distribution of ratings for the sexes separately. The most obvious finding is that males rate themselves as masculine, and females as feminine, a finding that is perhaps not surprising. However, about ¾ of both males and females make use of the extreme ratings of 6 or 7. The number of those with strong feelings of masculinity or femininity is notably higher than the proportion of people who would be found by self report to be "stereotyped" as masculine or feminine on personality measures of sex

TABLE 1. Distribution of Masculine and Feminine Ratings for the Sexes Separately

Females (N = 247)				Males (N = 221)			
Masculine Rating N = 226		Feminine Rating N = 246		Masculine Rating N = 219		Feminine Rating N = 192	
7	0.4%	7	35.4%	7	48.4%	7	1.0%
6	1.3%	6	38.2%	6	26.0%	6	0.5%
5	4.4%	5	11.4%	5	8.7%	5	1.0%
4	11.9%	4	7.3%	4	11.0%	4	6.3%
3	22.1%	3	5.7%	3	2.3%	3	4.2%
2	20.4%	2	2.0%	2	1.8%	2	19.3%
1	39.4%	1	0.0%	1	1.8%	1	67.7%
Mean = 2.274		Mean = 5.841		Mean = 5.945		Mean = 1.594	
Standard Deviation = 1.322		Standard Deviation = 1.257		Standard Deviation = 1.403		Standard Deviation = 1.117	

role, such as the Bem Inventory. Results using the Bem typically find that somewhat more than ⅓ of males report themselves to be what has been called "masculine" or "instrumental," but not "feminine" or "nurturant." That is, they report that they are independent, assertive, aggressive, but not warm, sensitive, and fond of children. About ⅓ of females report themselves to be expressive and nurturant but not instrumental and these have often been referred to as "feminine" females. Other measures result in different percentages, but none report, on the average, that more than half of the respondents are strongly sex role stereotyped. The percent of males who are noted as androgynous ranges from 19 to 29 and of females from 20 to 33 (5).

How Many Androgynous

A variety of findings like these suggest that males are somewhat more likely to be stereotyped than are females. This means both that they are likely to attempt to demonstrate stereotyped male traits and also that they are likely to avoid ascribing to themselves the characteristics of the other sex. That showed up in these data where 87% of males strongly denied femininity by choosing a 1 or 2 rating while only 59.8% of females—almost 30% fewer—used a 1 or 2 masculine rating. The females were also more willing to choose the higher masculine ratings—18% of females had masculine ratings of 4 or higher while only 8.8% of the males had feminine ratings of 4 or higher.

That is, while both sex-role theorists and psychologists in general now seem to suggest that in some sense one can be both masculine and feminine, this does not seem to be a notion that is accepted by the majority of people in general. For those who believe that it is healthier not to be stereotyped, this may seem to be a disturbing finding. However, before reaching that position, it would be helpful to know more about what the terms masculine and feminine mean to people in everyday usage.

Black, Stevenson, and Villwock (3) noted that, for college students, masculine and feminine are more likely to be interpreted in terms of physical characteristics than personality traits or behavior. Analysis of our present data from high school students is confirming this. That is, the most frequent kind of response used when judging others as masculine or feminine was a physical characteristic—sometimes one that referred to a permanent characteristic such as build or height, or more often some that referred to what we consider changeable physical characteristics such as wearing jewelry or makeup. We investigated whether any of the background variables were related to the ratings. In order to answer this question, a multiple regression analysis was done which included the variables of gender, age, school, order of the ratings, intended final level of education, mother and father education, and whether or not the mother was employed outside the home.

The analysis for the entire population of masculine ratings as affected by all of these variables found two significant predictors. The variable of gender accounted for 64.4% of the variance. There was a smaller but statistically significant effect of order. Specifically, ratings of masculinity were higher when they were done after rating one's femininity than if the masculine ratings were done first.

Analysis of the ratings for femininity found only a major effect of gender with 77% of the variance accounted for by whether the rater was male or female. Because of the overwhelming effect of gender, analyses were also done for the sexes separately.

The analysis of only male responses again found the effect of order upon masculinity. The mean score for masculinity, rated first, was 5.55 while the mean score for masculine ratings done after feminine ratings was 5.83. In addition, there was a difference between schools. Males in the public school gave more extreme scores than those in the Catholic School: that is, they rated themselves as more masculine (6.05 vs. 5.78) and less feminine (1.43 vs. 1.85).

The analysis of female responses showed neither of the above effects. There were effects associated with the variables of education. Those females who indicated that they expected to obtain at least a college bachelors degree differed from those with lesser aspirations. Generally it is found that those who have more education are less stereotyped. Our findings are counter to this, however. That is, those females who aspired to a bachelors degree or more reported themselves as more feminine (6.09 vs. 5.53) and less masculine (2.0 vs. 2.6). It is of course possible that this will change when they, in fact, are college graduates. This is suggested by the additional finding that those girls whose mothers are college graduates are less likely to report themselves at the extreme of femininity (5.5 vs. 5.9).

The results of this paper suggest that many persons interpret their own masculinity and femininity as being an all or none phenomenon like male or female. This is in contrast to the way these concepts are presently conceptualized by social scientists. Perhaps the explanation for this contradiction is that social scientists do not use the same meaning for these terms as do people in everyday life. One of the important tasks for theorists and those concerned with gender is to determine what it is that these terms mean, both when applied to oneself and when applied to others.

Acknowledgments

We would like to express our appreciation to the following persons: Michael Botts for data analysis and Richard Roe for the table. This research would not have been possible without the cooperation of the staff and students of Mater Dei High School and Adams Central Community Schools.

Literature Cited

1. Bem, S.L. 1974. The measurement of psychological androgyny. J. of Consult. and Clin. Psychol. 42: 155-162.
2. Bem, S.L. 1975. Sex role adaptability: One consequence of psychological androgyny. J. of Personality and Soc. Psychol. 31: 634-643.
3. Black, K.N., Stevenson, M.R., & Villwock, D.N. 1986. What do "masculine" and "feminine" mean in everyday usage? Proceedings of the Indiana Academy of Science, Volume 95.
4. Constantinople, A. 1973. Masculinity-femininity: An exception to a famous dictum? Psychol. Bull. 80: 389-407.
5. Cook, E.P. 1985. Psychological Androgyny. Pergamon Press, Elmsford, N.Y.
6. Spence, J.T., & Helmreich, R.L. 1978. Masculinity and femininity: Their psychological dimensions, correlates, and antecedents. University of Texas Press, Austin.

Kindling Rates in Sprague Dawley Rats as a Function of Copper and Nichrome Electrodes

Martin B. Wolske, Eliza Hui Chien Lian and Curtis K. Leech
Department of Psychology
Anderson College
Anderson, Indiana 46012

Introduction

Kindling is the process of developing experimental epilepsy through repeated electrical brain stimulation over a period of time (4). It has been found to be a generalized phenomenon, occurring in a variety of animals (e.g. frogs, mice, rabbits, rats, cats, monkeys, and for therapeutic reasons, humans) (11). Because of its reliability, kindling has been widely used as a dependent variable in studies that have ranged from the effects of epileptic medications (11) to the testing of kindling as a neurological model of normal brain function (4, 6). It appears that many changes that occur in neural activity are reliably reflected in kindling rates (11).

The Wistar, Royal Victoria and Long Evans strains of rat have been the primary targets of these investigations. However, the Sprague Dawley rat strain, which has not been used very often, has great appeal because of its gentle disposition (appreciated by students not used to handling rats), and its wide use in behavioral studies. Preliminary research in our laboratory has found that the Sprague Dawley strain has been somewhat more refractory to kindling procedures than the other strains. However, Leech (5) reported pilot data that found the Sprague Dawley strain kindled faster than the other strains. One primary difference between the two studies was that Leech (5) had used nichrome wire electrodes, whereas copper wire had been used in the second study because of its availability and economy. The present study was undertaken as a first step in establishing normative data on kindling rates in Sprague Dawley rats, and determining if copper wire can be used effectively in brain stimulation studies.

Method

Twenty-six male Sprague Dawley rats were obtained from Holtzman Co. (Madison, Wisconsin). They weighed approximately 300 grams at the time of surgery. They were individually housed in a room that was kept at approximately 24 degrees Celsius and had lights that turned on at 6:00 AM and turned off at 6:00 PM. Purina Lab Chow and water were available at all times, except 12 hours prior to surgery when food was removed. Tetracycline was added to their water prior to and following surgery to avoid respiratory infection.

After one week of regular handling, the rats were anesthetized with Nembuta (50mg/kg, i.p.). Bipolar electrodes, composed of either enamel coated copper wire (.0213 cm in diameter) or diamel coated nichrome wire (.0217 cm in diameter) were fabricated by soldering the wire to Amphenol pins (220-PO2). These were then twisted, dipped into epoxylite for additional insulation, and baked for 6 hours at 120 degrees Celsius. The wires were then tested for continuity, cut to length, and were stereotaxically implanted in the amygdala-piriform region of either hemisphere.

One week following surgery, both the nichrome and copper groups were subdivided into "threshold" and "control" groups, each of which received a different treatment on the first day. The threshold group was tested for after discharge (AD) threshold utilizing a procedure similar to that outlined by McIntyre et al. (7). Each rat was stimulated at increasing intensities, with an intertrial rest period of one minute between stimulation onsets. The procedure started with a two second train of 60-Hz, monophasic square wave (1 msec pulse duration) at 35 uA, delivered from a Grass SD9 stimulator fed thorugh a Grass constant current unit, where the polarity was reversed daily. The entire sequence was: 35, 50, 75, 100, 150, 200, 300 uA. If AD was observed on a trial, the animal was not stimulated again that day. To reduce the risk of brain damage, 300 uA was not exceeded. The control group, by contrast, received the same stimulation parameters as the threshold group, but only at an intensity of 50 uA. Twenty-four hours later, and every twenty-four hours thereafter, both groups were stimulated at 50 uA. This was continued for 30 days or until 6, stage 5 convulsions (rearing and falling with clonus) were exhibited (11).

Following the 30 day stimulation period, AD thresholds were reassessed on the 8 rats in the threshold group which did not achieve 6, stage 5 convulsions.

Animals that had not kindled after the 30 day period were randomly divided into two groups. One group was given 200 uA (other stimulation parameters were the same as previously described) for 10 days to determine if their prior level of current was insufficient to provoke kindling. The other group was held as a control group for possible brain damage differences due to the stimulation at 200 uA for 10 days.

Following completion of testing, the rats were perfused with 10% formalin. The brains were then frozen and sectioned through the areas of the electrode tract. Selected sections were mounted on slides, stained with thionin, and examined microscopically.

Results

Histological analysis indicated that three rats had electrodes outside of the amygdaloid-piriform cortex area, and were eliminated. Three additional rats were eliminated due to a short circuit in the electrode, death following surgery, or the electrode becoming detached from the head.

The median number of stimulations (days) needed to produce AD, stage 1 convulsions (e.g. eye blinking and repetitive mouth movements), and stage 5 convulsions, for copper and nichrome electrode groups, appear in Table 1. Medians were used because not all subjects developed convulsions. As can be seen, the nichrome electrode group had a lower median number of daily stimulations than the copper electrode group for each effect listed in Table 1. However, only the fourth comparison of the number of days of AD needed to produce the first stage 5 convulsion, using the Mann-Whitney U test, was statistically significant ($z = 2.485$, $p < .05$). The second comparison of daily stimulations needed to produce a second AD had borderline statistical significance ($z = 1.774$, $p < .1$). The first and third comparisons were not statistically significant.

Table 1. Medians and ranges for afterdischarge (AD) and convulsion measures for copper and nichrome groups. Please note that "30+" should be read as exceeding the 30 day limit when testing was terminated.

Measurement	Copper		Nichrome	
	Median	Range	Median	Range
Days to first AD	25	3-30+	6	1-30+
Days to second AD	+	20-30+	7	2-30+
Days of AD to first stage 1	+	1-30+	5	2-30+
Days of AD to first stage 5	+	+-30+	8	7-30+

Table 2 shows the same measures as Table 1 for the animals that were later run at 200 uA. None of the comparisons between copper and nichrome groups were statistically significant at this current level.

Comparisons of AD threshold measurements between copper and nichrome groups showed borderline significance for the first threshold assessment while the second threshold assessment that followed the 30 day stimulation period was not significant ($z = 1.8473$, $p < .1$; $z = 1.51807$, $p \geq .129$, respectively).

TABLE 2. Medians and ranges for afterdischarge (AD) and convulsion measures for copper and nichrome groups that received 200 uA after 30 days at 50 uA. Please note that "40+" should be read as exceeding the 40 day limit when testing was terminated.

	Copper		Nichrome	
Measurement	Median	Range	Median	Range
Days to first AD	25	3-40+	32	6-34
Days to second AD	33	20-40+	33	7-35
Days of AD to first stage 1	2	1-40+	2	1-5
Days of AD to first stage 5	11	6-40+	7	5-40+

Where possible, kindling rates for the Sprague Dawley strain were then compared with data on Wistar rats, obtained from a study by McIntyre and Roberts (8). These data are listed in Table 3. Comparisons using t-tests found that the Sprague Dawley rats had significantly higher initial AD thresholds ($t(20) = -6.507$, $P < .001$) than the Wistar rats. Further, the Sprague Dawley rats showed a significantly shorter AD duration ($t(20) = 2.832$, $p < .05$) and duration of clonus ($t(20) = 3.704$, $p < .001$) than the Wistar rats. The kindling rate in days could not be statistically compared because McIntyre & Roberts used means, whereas the present study used medians.

TABLE 3. Afterdischarge (AD) threshold and kindling rate (number of days of AD to first stage 5 convulsion) for Wistar and Sprague Dawley strains.
Note: Only the median was available for the kindling rate in Sprague Dawley.

Group	N	AD threshold (uA)		Kindling rate (No. of stim)	
		X	SD	X	SD
Wistar	18	43.9	4.8	8.7	1.9
S.D.	4	112.5	47.9	5	

TABLE 4. Mean time, in seconds, for after discharge (AD) duration, latency to clonus, and duration of clonus for Wistar and Sprague Dawley Strains. Data from the last five convulsions were used.

Group	N	AD duration		Latency to clonus		Duration of clonus	
		X	SD	X	SD	X	SD
Wistar	18	78.1	15.2	7.5	2.1	45.1	4.2
S.D.	4	56.3	21.0	4.9	1.0	35.6	6.6

Discussion

The results clearly show that copper electrodes are less effective than nichrome for kindling convulsions. This was indicated by the significantly fewer number of stimulations required to produce stage 5 convulsions in rats with nichrome wire, and the lower AD thresholds found in the nichrome group. The most plausible reason for this appears to be that copper wire causes neural damage that retards the kindling process. Babb and Kupfer (1), found that copper deposits resulted in necrosis and phagocytosis in the neural tissue of rats. Although the present study found no apparent gross tissue damage in the histologies of the rats, the possibility of necrotic and phagocytic damage could not be ruled out.

Further, several studies have suggested that kindling is the result of tissue damage caused by the kindling procedures (11). The present study suggests that this damage could not be due to the necrotic and phagocytic damage found by Babb and Kupfer from copper electrodes, since these electrodes were the more refractory to the kindling procedures. Indeed, damage produced by necrosis and phagocytosis seems to retard the kindling process, as evidenced by the increased number of stimulations required to produce convulsions in the copper group as compared to the nichrome group.

The present study also suggests that the Sprague Dawley rats are less consistent than the Wistar rats in their manifestations of kindling, although as Leech (5) reported, they kindle more rapidly at 50 uA. However, the difference in the kindling rates suggested by the means, includes the differences in the initial AD threshold between these two strains. Measures from the first AD to the first stage 5 convulsion are needed for the Wistars to make this a more meaningful comparison. A further difference between strains is seen in the shorter latency to clonus and shorter durations of AD and clonus for the Sprague Dawley rats. This would seem to suggest faster breakdown of inhibitory circuits, but also faster recovery after that breakdown. However, some Sprague Dawley rats occasionally have "bimodal" or even "trimodal" distributions for both AD and convulsive activity. In other words, there is occasionally a break in AD and/or convulsion activity (ranging from 2 to over 75 seconds) before a recurrence of the AD or convulsion activity. This may be again followed by a break and a third recurrence of AD or convulsive activity. This variability occurs often enough in Sprague Dawley rats to consider it typical of the strain, and appears different from the occasional post convulsive episodic bursts of spiking activity described by Goddard et al. (4). The neurological differences suggested by these different convulsive patterns is intriguing and warrants further study. Also worth mentioning was the occasional spiking seen in 5 of the rats after the start of the experiment, but before stimulation on any given day. Racine (10) noted a similar occurrence in 20% of his rats. It is interesting that this was found only in the copper group (50% of the copper group had this occur at least once). Several times when this occurred the rats were left on the EEG machine for up to 20 minutes prior to stimulation. During that time, there was no evidence of the spiking activity abating.

In conclusion, the present study found that copper wire was less efficacious than the nichrome wire for producing kindling, and should, therefore, be avoided. Further, The Sprague Dawley strain was more inconsistent in its manifestations of kindling than the Wistar strain. It is also suggested that these strain differences reported here may serve as a useful independent variable in studies exploring inhibitory processes, but may not be preferable to the inbred strains of mice used by Leech (5) and Leech and McIntyre (6).

Acknowledgment

Special thanks is directed to Drs. William Farmen and G. Lee Griffith for their valuable assistance in data analysis. Both also provided statistical help, encouragement, advice and constructive criticism. This research was partially supported by the Center for Public Service, The Psychology Department and a Faculty Development Grant to C.K. Leech, all at Anderson College.

Literature Cited

1. Babb, T.L. and Kupfer, W. 1984. Phagocytic and metabolic reactions to chronologically implanted metal brain electrodes. *Experimental Neurology* 86:171-182.
2. Carrington, C.D., Ellinwood Jr., E.H. and Krishnan, R.R. 1984. Effects of single and repeated alcohol withdrawal on kindling. *Biological Psychiatry* 19(4):525-537.
3. Frank, R.A. and Stutz, R.M. 1982. Behavioral changes induced by basolateral amygdala self-stimulation. *Physiology and Behavior* 28:661-665.
4. Goddard, G.V., McIntyre, D.C. and Leech, C.K. 1969. A permanent change in brain function resulting from daily electrical stimulation. *Experimental Neurology* 25(3):295-330.
5. Leech, C.K. 1972. Rate of development of electrically kindled convulsions compared to audiogenic seizures and learning ability in six inbred mouse strains. Ph.D. Dissertation, University of Waterloo.
6. Leech, C.K. and McIntyre, D.C. 1976. Kindling rates in inbred mice: An analog to learning? *Behavioral Biology* 16:439-452.
7. McIntyre, D.C., Nathanson, D. and Edson, N. 1982. A new model of partial status epilepticus based on kindling. *Brain Research* 250:53-63.
8. McIntyre, D.C. and Roberts, D.C.S. 1983. Long-term reduction in beta-adrenergic receptor binding after amygdala kindling in rats. *Experimental Neurology* 82:17-24.
9. McNamara, J.O., Peper, A.M. and Patrone, V. 1980. Repeated seizures induce long-term increase in hippocampal benzodiazepine receptors. *Proc. Natl. Acad. Sci.* 77(5):3029-3032.
10. Racine, R. 1972. Modification of seizure activity by electrical stimulation: II. motor seizure. *Electroencephalography and Clinical Neurophysiology* 32:281-294.
11. Racine, R. 1978. Kindling: The first decade. *Neurosurgery* 3(2):234-252.
12. Shavit, Y., Caldecott-Hazard, S. and Liebeskind, J.C. 1984. Activating endogenous opioid systems by electroconvulsive shock or footshock stress inhibits recurrent kindled seizures in rats. *Brain Research* 305:203-207.
13. Welsh, K.A. and Gold, P.E. 1984. Attenuation of epileptogenesis: Proactive effect of a single ipinephrine injection on amygdaloid kindling. *Behavioral and Neural Biology* 40:179-185.

SCIENCE EDUCATION

Chair: Walter A. Cory, Jr.
3512 Windcrest Drive
Bloomington, Indiana 47401 (812) 339-4738

Chair-Elect: Cheryl L. Mason
#216 Chemistry Building
Purdue University
West Lafayette, Indiana 47907 (317) 494-8524

ABSTRACTS

Friends with Fins: Using Fish as an Educational Tool. Claude D. Baker, Indiana University Southeast, New Albany, Indiana 47150.——At most academic levels, fish study provides an excellent avenue for developing an understanding and appreciation of a variety of science concepts. Information and handouts will be presented on a variety of subjects, including: setting up freshwater and marine aquaria, anatomy, fish watching, use of taxonomic keys, ecological concepts, audiovisual materials and fish tasting.

Experiential Training: Evaluation and Grading of Extended Field Trip Courses. Carl Christenson, Jacqueline Christenson and Claude D. Baker, Indiana University Southeast, New Albany, Indiana 47150.——Experiential training involving field trip courses has been incorporated into many disciplines. Art classes often visit the museums in Europe; language classes visit a country where the language is spoken. In biology, personal visits to distant locations provide a fuller appreciation of earth's biomes. Despite the widespread popularity of academic credit for field trip courses, little information is available on evaluation and testing procedures used in this instructional modality. Our approach in creating performance referencing criteria has included use of "search images," on-site field notes, pre-trip classes and testing, post-trip objective exams, and rating of attitude and participation. Point totals for some seven areas provided an evaluation scheme which was translated into letter grades.

Project Map: An Evaluation of a Community. Karl K. King, Muncie Central High School, Muncie, Indiana 47306 and Rosalie J. Kramer, Indiana University East, Richmond, Indiana 47374.——Project Map illustrates how a lab exercise can be adapted to different age groups of students (middle school, high school, and college) to teach the basic concepts of topographical mapping and community evaluation. The project stresses group participation and cooperation as well as develops skills in using instruments such as a compass, transit, and scientific keys.

The Purdue Atmospheric Science Education Program for Junior High Science Teachers. John T. Snow, David R. Smith and Shawn B. Harley, Department of Earth and Atmospheric Sciences, Purdue University, West Lafayette, Indiana 47907.——A description is given of an atmospheric science program for junior high school (grades 5-9) science teachers that is being developed at Purdue University. The goals of the project include improving the atmospheric science background of 24 Indiana junior high science teachers and assisting the teachers in applying this acquired information in the classroom. Videotapes dealing with eight selected topics in the atmospheric sciences also are being developed with the intent to disseminate the tapes and supporting written materials on a nationwide basis.

In July, 1987, a four week instructional course in meteorology and education will be conducted at the Purdue West Lafayette campus. The 24 teachers selected to participate in the program will become familiar with the physical laws which govern meteorology and how these principles relate to other physical sciences. Through daily lab work, they also will gain ''hands on'' experience in making weather observations, doing weather analyses, and in making simple forecasts. Other activities planned for the program include education applications seminars, field trips, and talks given by guest speakers from the national atmospheric sciences and science education communities.

First Activities of the Physics Kind: Physical Science Activities for the Primary Grades

PATRICIA DODSON
Westlake Elementary School
Indianapolis, Indiana 46278
AND
RUTH H. HOWES
Department of Physics and Astronomy
Ball State University
Muncie, Indiana 47306

Introduction

Women and minorities, except for Asian Americans, are under-represented in the physical sciences and technical trades. These students tend to avoid physics, chemistry and technical courses in high school because they fear that they cannot "handle" the subjects covered. In addition, recent studies by national organizations have demonstrated general weakness in the physical science training of students in the United States, particularly when they are compared to their counterparts in Japan, China, the Soviet Union and other industrialized nations. This project applies to the physical sciences some of the techniques developed by EQUALS to encourage participation of women and minorities in mathematics. While many mathematics skills such as problem solving and measurement are common to mathematics and the physical science, science instruction also depends on the acquisition of content and the construction of an intellectual framework which can organize it. Therefore the methods which have proved successful in EQUALS in mathematics must be modified for use in science instruction.

The EQUALS program of the Lawrence Hall of Science at the University of California at Berkeley has a successful record of developing instructional activities to encourage the participation of women and minority students in mathematics where such students are traditionally under-represented. The EQUALS activities are designed both to remove the fear of math which women and minorities develop early in school and to build math skills such as spatial perception and logical thinking in which test results show women and minorities are weak.

Physical Science in the Elementary Classroom

The contents and vocabulary of the physical sciences are no more intrinsically difficult than those of biology and earth science yet few elementary classrooms stress them. There are three basic reasons for the conspicuous absence of physics from elementary classrooms. First many materials are designed by university professors of physics or science education who have little feeling for the skills, interests and attention spans of second graders. They tend to overestimate the time and resources available to the primary teacher who must cover not only science but also such vitally important subjects as mathematics and reading. Secondly many proposed physical science activities require supplies and equipment that are difficult to obtain and beyond the budgets of elementary schools. Finally many elementary teachers themselves fear physics and feel uncomfortable trying to teach it.

Introduction of physical science in the early grades will help to improve the physical science backgrounds of all students and to reduce the barriers of fear that prevent their enrollment in high school physics, chemistry and technical courses. If the physical sciences are familiar subject matter to female and minority students, they will be more likely to study them. Increasing coverage of relevant skills and concepts in the early grades will improve the level of physical science knowledge and skill among all students. Finally physical science provides many opportunities for introducing concrete illustrations of mathematical concepts and processes. Its early introduction thus reinforces mathematics education in these grades.

The dependence of science on both content and process puts science education, particularly in the early grades, between the Scylla of over-dependence on process which characterized the "discovery" method materials and the Charybdis of books which merely describe phenomena or introduce students to clever experiments with no attempt to construct an intellectual framework which will later form the backbone of the quantitative formulation of the physical sciences. For this reason, EQUALS science materials are designed in sets of activities which should be done sequentially in the classroom. The activities build necessary skills such as measurement and description and at the same time attempt to develop the framework by which the various contents of the different activities are related to each other. For example, the sequence of activities on motion described here first introduces the measurement of time and distance. Then the idea of direction in motion is added followed by the idea of speed which relates distance and time. Velocity relates time, distance and direction and is logically the next topic to be covered. Finally the sequence will introduce the idea of acceleration which is a change of velocity with time. This has been done in two steps: the change of speed with time and then the change of both speed and direction with time. Clearly second grade students cannot understand the quantitative relation among the various quantities, but the idea that they are related in a systematic manner can be taught early. The early introduction of technical vocabulary will also make later instruction in the physical sciences where students are also expected to grapple with mathematics less intimidating for them.

This project has designed activities to introduce the physical sciences in the elementary classroom. They have been developed by a second grade teacher and a university physics professor and tested on real live second graders in order to produce technically accurate materials which are of practical use in the elementary classroom. This project was funded by a Providing for Potential Grant from the Wayne Township School Corporation and money from the Carnegie Corporation of New York granted to the EQUALS Program at the Lawrence Hall of Science of the University of California at Berkeley.

Types of Activities

Stations are instructional activities which can be easily set up in the classroom for students to explore when they are early or have finished other work. In the EQUALs mathematics program, stations have been developed to teach important mathematics skills such as spatial visualization or problem solving. These activities are popular with both students and teachers and seem to be successful in teaching the skills they are designed to strengthen. This project has extended the use of stations to teach basic concepts in physics in the early grades. Since physical science concepts build on one another, it is logical to design stations as units which combine to present one set of ideas. The stations should be set up or done in sequences which will give the student a grasp of the skills and contents of one area of physical science. All stations have been designed for use in the very early grades. No expensive apparatus is necessary. Materials have been designed for easy use by the teacher. Wherever possible, the teacher only needs to xerox station materials. Use of these stations does not require that students understand every implication of the concepts presented nor the full meaning of the technical terms used, but by an early encounter with physics will reduce eventual fear of the subject and use of the jargon will give the words a familiar ring in students' ears. Stations use only one set of supplies and equipment for an entire classroom. They occupy little space and can be set up easily in the absence of any sort of laboratory facility.

Elementary children are often kinetic learners. Fortunately many concepts in the physical science lend themsleves to instruction as active games. Whenever possible, concepts have been packaged in the form of active games which will introduce skills and processes that will be re-enforced by station sequences. For example, the concepts of speed, velocity and acceleration are particularly ammenable to instruction by means of games. The teacher may use the games to explain concepts and skills which will later form the basis of station sequences.

The Motion Sequence

These seven stations deal with the description of motion in the jargon used in physics. Wherever possible, the station designed for use in the classroom has been backed up with a playground game which presents the same concepts.

The description of motion begins with the idea of measuring distance and time. The stations can begin with Zoo Secrets and Timely Turnup. These two stations introduce respectively the ideas of measuring distance and measuring time. Students are encouraged to experiment with the activities described in the Timely Turnup and to try the measurements in Zoo Secrets until they are comfortable with the measurement of space and time. Extra games have been created in each set to provide students more practice.

Zoo Secrets are animal picture puzzles that hide words which sometimes are used to describe motion. The child is given a ruler, the puzze picture and a set of cards with measurements on the front and a letter on the back. To find the hidden word, the student measures the lines of the picture in the order in which they are numbered and places the measurement cards in the correct order. He or she then turns the cards over and discovers the hidden work. The words are the physics terms used to describe motion and will probably be unfamiliar to second graders. The teacher should help the student pronounce the word and call his attention to the hint on the picture puzzle which defines the hidden term for that puzzle.

In the physical sciences, distances are usually measured in the metric system. In these activities, this is done simply by using centimeters as a matter of course rather than talking in terms of changing from inches to centimeters. Since young children are not familiar with measuring in inches, the use of centimeters will probably bother them less than it would older children. The teacher shows the children how to use a ruler and then lets them try Zoo Secrets. This station could also be done as an in-class activity with each student working on one of the puzzles at his ownd esk but this uses valuable class time. Stations teach during extra moments during the day.

Timely Turnups is an exercise in the measurement of time. The puzzle board ask questions answered by measurements of time such as "How long does it take to ski across the room?" The student is given a deck of puzzle cards with times and letter on them. He or she chooses the card with the appropriate time and places it over th question is answers on the puzzle board. The letters then spell out a physics term use in the description of motion.

The data used in the puzzles will obviously have to be adapted to different classroom since it will take varying amounts of time for children to run across different rooms Children should be encouraged to experiment and time themselves to see exactly ho long it will take them to run or crawl across the room. This provides practice in measu ing time as well as in conducting an experiment. The teacher should encourage studen to try the experiment by simply answering the question "How long does it take to craw across the room?" with "Why don't you try it and see?" Part of the point of the exe cise is to give students a feeling for how long times are. A second is the standard ur of time in the physical sciences and is therefore used here although it is shorter th that with which most young children are used to dealing. As in Zoo Secrets, the vocabula words hidden in the puzzles have value in their own right and attention should be call to the meaning of the hidden words although students may not remember them.

The next staion in the sequence, Treasure Hunt, introduces the idea of direction into the concept of moti on. The station is played on a map of a treasure island on which is a numbered grid and the outline of a compass. The student is given directions from a landing in terms of number of boxes to move and the direction in which to move. The directions lead to the squre under which the "treasure" is buried. As the student searches the grid for the treasure, he/she learns that the direction in which one moves is as important as the size of the motion. If the teacher wishes, he/she can provide the student with a sticker or some other treasure when the student is successful in the game. The concept of direction is basic to introductory physics and often is neglected until the student enters high school science. Treasure Hunt attempts to introduce it earlier so that the use of co-ordinates is not a culture shock to the older student. This activity can be done as an in-class activity with each student provided with a copy of the map and a set of co-ordinate clues.

The Animals' Race introduces the idea that speed measures how much distance is covered in each second. This is the second step of the structure of ideas used to describe motion in general. It introduces the idea that you need a relationship between time and distance to describe motion. The teacher can demonstrate this very easily by walking slowly across the classroom and then walking the same distance quickly. Ask the students what was different even though the distance you covered was the same. In real life, the unit of time is generally the second and the unit of distance is the meter. In the station, one turn is the unit of time and each animal can cover a set amount of distance in each turn. That distance is determined by the length of the cardboard strip associated with that animal. Moves are made in turn along paper race track by turning the strip over and moving one length each turn. The students quickly learn that the rabbit wins every time if the animals move only in one direction because it has the longest strip. They get bored with this game quickly.

To use the activity as a learning game, the teacher designates a race track on the playground or in the classroom and the children choose who will represent each animal in the game. The different animals can take different numbers of steps each turn. For example, a rabbit might take five steps while a turtle can only take one. You can make up your own cast of animals or follow the suggestions of the stations. The children may prefer super-heros to animals. Let the children run a few races. Of course, one child always wins and the teacher should point out that that is because he or she covered the most distance during teach turn. This sounds terribly obvious but many college freshmen have real trouble grasping it when it is written down in math terms.

The Confused Animals' Race introduces the idea that direction as well as speed is important in getting to a finish line. This is the physics concept of velocity which is the speed of an object and the direction in which it moves. The Confused Animals' Race involves moving the animals at a set speed by turning strips as was done in the Animals' Race. Each animal is allowd to move a fixed length each turn. This time the animals don't move straight toward the finish line but can go in any direction. The students spin a direction spinner to find out which direction they will move in each turn. This time the fastest animal does not always win. It depends on the direction in which the animal moves. Associated reading is clearly Aesop's fable, "The Tortoise and the Hare" since the lesson obviously applies.

The Confused Animals' Race is also easy to present as a physics game. As for the Animals' Race game, the teacher must designate a race course on the playground or in his or her room. The starting point should be near the center of the course. On the playground, a basetball court works well with a finish line at one end of the court and a starting point near the center. The children again select who will be which animal and the teacher specifies the speed at which that animal can run, that is the number of steps it may take during each turn. If the chilren have played the Animals' Race, they will all want to be the fastest animal which won that race. Each animal will choose a partner to spin the spinner for him or her. To play the game, the animals start in the starting box. The partner spins the spinner and the animal moves his appropriate number of steps in the direction that the spinner shows. The animals take turns moving. If an animal runs off the race course, he loses a turn. The winner is the first animal to cross the finish line. Obviously the fastest animal will not always win this race. The teacher should stress the importance of direction as well as speed in determining the position where the animal ends up. If the teacher uses the word velocity to describe the animal's speed and the direction in which it goes, the children will not understand the word in detail but they will soon associate it with speed and direction.

It is very important to start even very young children working with direction since it is central to beginning physics in high school. It is a hard concept in the abstract and it will be of real use to students if we can find a way to make them instinctively comfortable with it. Students should do The Animals' Race before they try the Confused Animals' Race. The other essential concept in The Animals' Race is change. Most mathematics and science activities stress the total value at which we arrive but physics deals in the discussion of changes. Whenever possible, the teacher should talk with students about how much the animal's position has changed and how fast it has done so.

The final concept in the series is acceleration which is the change in velocity during each time interval. Acceleration is the final step in the description of motion since it involves measurement of distance and time, direction, speed and velocity. Velocity can change when an object speeds up or slows down or when it changes the direction in which it is traveling. Traffic Jam involves acceleration by increasing or decreasing speed. The players are cars trying to reach the end of several blocks in a traffic jam. They take turns rolling a die to determine how many blocks they move in that turn. The teacher should point out that this game is different from the Animals' Race because the players travel different distances each turn instead of always going the same distance each turn. Probably this will strike children as terribly obvious but it is important to start them thinking about the way in which they change the number of turns it takes them to reach the end of the board. On the playground, the board is the course used for the Animals' Race which now represents a busy street. Players are cars and roll a die to see how many steps they are allowed to take each turn. The first player over the finish line wins.

The Elastic Legged Pirate can change both his speed and the direction in which he is traveling. The game involves both a spinner to determine direction and a die to determine how many squares the pirate can move in one turn. It will probably work better if the students have tried the Animals' Races and Traffic Jam first. Each player takes a turn spinning the spinner and rolling the die. He moves the number of squares on the die in the direction shown by the spinner. If he goes off the board, the student loses a turn. All players start at the landing and the first player to reach the treasure wins. In this game, you will need to mark the spinner so that the players move north, south, east or west or on one of the diagonals. This will help to prevent confusion on how to count squares for each turn.

The Elastic Legged Pirate can be played as a game on the same course as the Confused Animals' Race except that the players now need to reach a special region of the course where the treasure is hidden. In this game, each pirate will need a partner. The partner spins a spinner to see in which direction his or her pirate will travel and also rolls a die to see how many steps the pirate can take in each turn. Thus the pirates will travel in changing directions and at changing speeds. The teacher should use the word acceleration to describe a change in either a pirate's speed or the direction in which he or she is moving. To play the game, the pirates take turns starting in the starting box and moving the required number of steps in the direction the spinner tells them to go. If a player runs off the course, he or she loses a turn. The first pirate to reach the treasure wins.

These activities complete a very solid framework for describing motion. It is the basis of the first several weeks of a high school physics course which simply does the same thing in terms of mathematical formulas. Second graders will not have much feel for numbers and certainly not for formulas but these exercises should give them a feel for the relationships involved and how changing time or distance affects other quantities like velocity or acceleration. Just a feeling for the involvement of direction in motion should help students get a feel for beginning physics. Hearing the vocabulary will make it less intimidating for students in more advanced science courses. The intent is not to transform second graders into physicists or even to provide them with a technical vocabulary for describing motion but to give them an early encounter with the relationships involved and a feeling for the vocabulary and concepts used. In addition to describing motions around them, they will begin to construct a conceptual framework upon which they can later hang numbers.

Needless to say, the conceptual design of the stations and games changed as they were tested on a lively group of second graders at Westlake Elementary School. The games were not in the original project design and were added to help kinetic learners understand the concepts presented. Two stations were added to the original five (Traffic Jam and The Elastic Legged Pirate). Mechanisms for the teacher to introduce the concepts to students before they encountered the games were developed after initial confusion resulted in some of the stations. A set of teacher notes was prepared to give the teacher some written words to describe the materials. The formats of the activities themselves were modified to a form suitable for use in the elementary classroom. Boards became simpler and instructions were written so that second graders could understand them. Expected problem areas did not materialize. For example turning the cardboard strips used in the Animals' Races was not difficult for the children. On the other hand, unexpected problems materialized. For example, the Elastic Legged Pirate couldn't be taught as it was originally used because it added the concepts of changing velocity by changing speed to the concept of changing velocity by direction. Traffic Jam was introduced as an intermediate stage. The materials still have unresolved problems. We would like to include greater emphasis on career options and the importance of staying involved in science in the sequence. A pre and post test sequence has been developed but has not yet been tried on students using the full station sequence.

At the time of this writing, the sequence shows promise of offering a workable introduction to the study of motion in the second grade. Classroom observations indicate that students who have used the activities seem to grasp the concepts presented and enjoy the activities. Their favorite activity was overwhelmingly Treasure Chest, perhaps because the teacher presented them with a real treasure from a cardboard treasure chest when they got the correct answer to the puzzles. On the basis of our observations, we feel students learned the most from Elastic Legged Pirate since they had to understand and to some extent synthesize the materials presented in the other activities in order to understand this final game. The materials on motion are approaching a final form and we hope to continue the project by developing other first activities of the physics kind.

Weight Titrations: A Forgotten Art?

A.J.C.L. Hogarth
Department 417
Ross Laboratories
625 Cleveland Avenue
Columbus, Ohio 43216

A Brief History of Weight Titrimetry

Weight titrimetry has been a part of analytical chemistry for many years; it certainly predates volumetric analysis by at least half-a-century if not longer. The clear reason for this state of affairs is that while weighing was a well-developed method of measurement, the standard glassware needed for volumetric analysis was not available, at least not until the beginning of the nineteenth century when such French chemists as Descroizilles started to develop it.

One of the first recorded analyses by what is clearly weight titrimetry was by Guillaume Homberg in 1699 (7). He titrated potash with nitric acid by weighing the former in small portions into the latter until reaction ceased. The end-point of this reaction would certainly have been cessation of effervescence but Homberg did not mention this in his paper. Some thirty years later in 1729 Claude Geoffroy read a paper to the French Academy concerning his researches with vinegar: he added weighed quantities of dry potassium carbonate to vinegar until the bubbling stopped, a clear indication of the reaction end-point (7).

Other notable workers were Francis Home in 1756 who, in his book "Experiments on Bleaching", described the analysis of various liquors and solutions by weighing; William Lewis, in 1767, in a monograph entitled "Experiments and Observations on American Potashes with an Easy Way of Determining Their Respective Qualities" described various methods of titration based upon weighing; Carl Friedrich Wenzel in 1777 wrote a book dealing with "titrimetric synthesis" in which he used weight titration as a method of investigating the stoicheiometry of certain reactions; and Louis Bernard Guyton de Morveau who, in 1793, used the method to investigate the titration of carbonate solutions with lead solution.

Evidently the method has quite a distinguished history which was submerged almost completely by the advent of volumetric analysis. This does not mean, however, that the method was totally lost because periodically papers have appeared in the literature dealing with analyses using weight titrimetry. For example Washburn (9) used the method at the turn of the century for the determination of arsenious acid iodometrically. His apparatus was a little complicated but the results he obtained showed excellent precision, about 0.1ppt.

Several designs for apparatus have appeared in the literature, the most common one being that of Friedman and LaMer (3). This is shown in Figure 1 and is essentially a modified separating funnel with side hooks to support it in a balance chamber, a drawn tip for drop delivery, and a ground glass cap for the tip to prevent loss by evaporation. A weight buret constructed from a polythene wash bottle was successfully used by Seils, Meyer and Larsen for the determination of plutonium (VI) with iron (II) (8). In 1969 Davenport published a short paper dealing with the use of plastic baby-bottles in general chemistry laboratories for several experiments (2).

More recently, however, Kratochvil has revived a little interest in the method as a convenient way of conducting titrations with non-aqueous solvents (6). He has exended the method for use with a modern top-loading balance attached to a small computer (5). This arrangement has many possibilities largely because of the flexibility of the com-

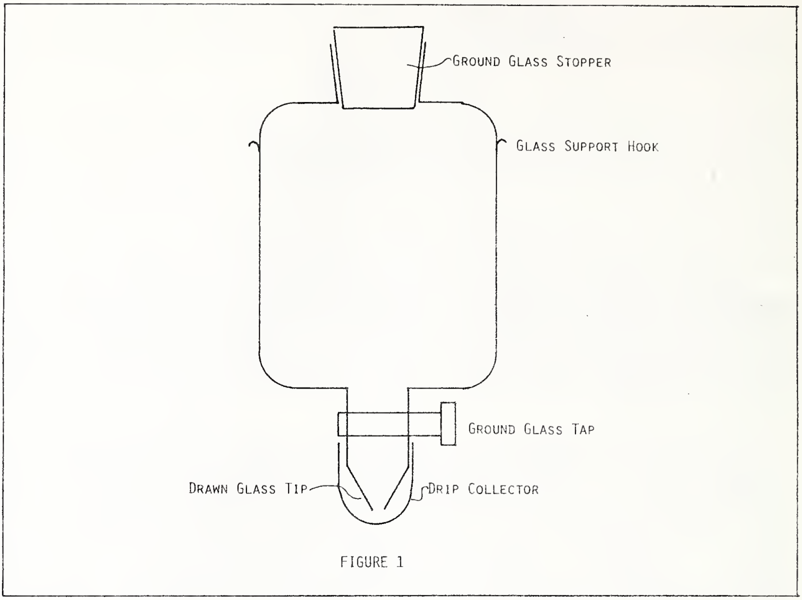


FIGURE 1. Classical weight burette.

puter, and will allow the simultaneous titration and plotting of a variety of titration curves.

The object of this short paper is to show the value and utility of this technique for teaching some of the principles of analysis, stoicheiometry and quantitative method as applied to simple chemical systems. The experiments that will be described, although originally devised for a freshman general chemistry class, could, with little modification, be used in high schools or introductory analytical chemistry classes.

The Advantages and Uses of Weight Titration

1) The apparatus used is less expensive and often more durable than that for volumetric analysis.
2) A weight titration may be more precise, and can often be made more so, whereas there is a limit to the corresponding volumetric titration (1).
3) Changes in calibration of glassware due to fluctuations in temperature are non-existent.
4) Syringes or small plastic dispensing bottles are easier to fill and clean than burets and pipets, and they do not break as readily.
5) Syringes and small plastic dispensing bottles require far less practice to use effectively (4). Burets and pipets often require a great deal of effort for correct use.
6) There is no confusion between 'TO CONTAIN' and 'TO DELIVER' notation, i.e. how long to allow the apparatus to drain?
7) There are savings in time for titration as well as in the quantities of reagents used.
8) Titration can be very rapid, e.g. twelve titrations in one hour, and this includes all the weighings!
9) Automation of the titration is possible with the use of a modern top-loading balance.

10) Titration is possible with volatile or classical toxic reagents with convenience and relative safety. For example:
    a) Arsenic standardization with oxidizing agents.
    b) Titration with expensive reagents, e.g. silver nitrate.
    c) Titration of plutonium. The apparatus is so inexpensive that it may be disposed of immediately after use.
    d) Titration with reagents contained in volatile or non-aqueous solvents, e.g. caffeine using perchloric acid in glacial acetic acid, or the Karl Fischer titration for water.
    e) Titration with somewhat unstable reagents, e.g. titanous chloride for the azo group in certain dyes.

The Titration Procedure and Apparatus

The procedure adopted for weight titrations is quite a simple one and is as follows:

a) Solutions are prepared by dissolving a weighed quantity of analyte or titrant in a weighed amount of solvent. Usually both the solvent and solute are weighed into a simple plastic dispensing device (Figure 2a). Another way of doing it is to weigh both solvent and solute into a stock vessel for mixing and then dispense from a syringe (Figure 2b). Syringes present a problem in that they frequently come with a needle, and this does occasionally result in disposal difficulties.

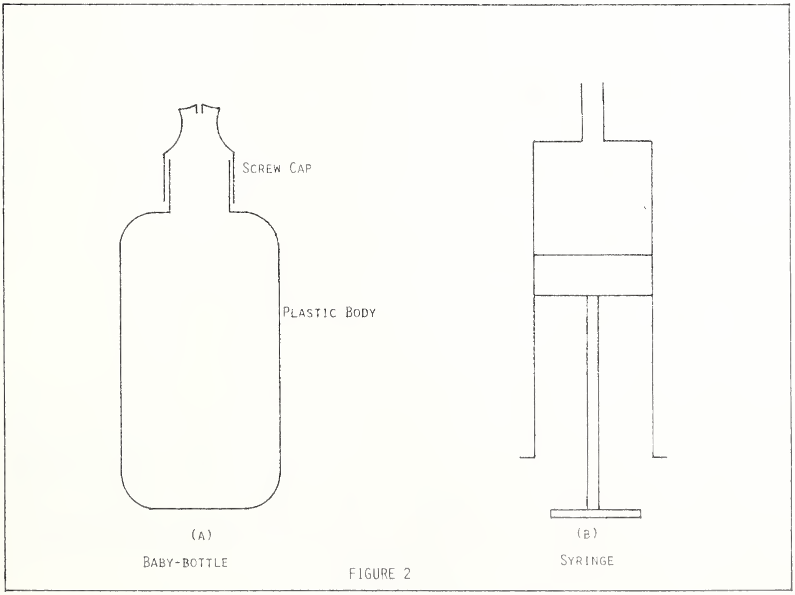


FIGURE 2. Commonly available devices for weight burettes.

b) Both the analyte and titrant are weighed for the purposes of the titration. Either may be a solid but one, at least, should be a solution for the sake of convenience. If the titrant is a solid it may be dispensed from a carefully held bottle, or it may be titrated with the analyte.

c) A suitable end-point detector should be chosen: visual indicators are usually very convenient, e.g. colorimetric or cessation of gas evolution. The experiment could be made more interesting for advanced students by using an instrumental end-point detector, e.g. pH-electrode, thermometer, etc.

Comparing Weight Titrimetry to Volumetric Titrimetry

A) Titration of Solid Potassium Hydrogen Phthalate (KHP) with Sodium Hydroxide

A quantity of KHP is accurately weighed (ca. 0.3g-0.5g) into a small flask and dissolved in about 25ml of distilled water. Two drops of phenolphthalein indicator are added and the solution is titrated to a pink end-point with sodium hydroxide solution.

a) Results for Volumetric Titration

Nine titrations gave a value for the ratio (volume of sodium hydroxide solution/weight of solid KHP) of (31.67 ± 0.14)ml of solution/g of KHP with a precision of 3.6ppt. Taking one significant figure less in both the weighings and volume readings gave (31.69 ± 0.18)ml of solution/g of KHP with a precision of 4.2ppt.

b) Results for Weight Titration

Nine titrations gave a value for the ratio (weight of sodium hydroxide solution/weight of solid KHP) of (31.83 ± 0.10)g of solution/g of KHP with a precision of 1.9ppt. Taking one significant figure less in the weighings gave a value of (31.82 ± 0.10)g of solution/g of KHP with a precision of 2.2ppt.

Clearly there is little to distinguish between the two sets of titrations from the point of view of precision. If, however, they are compared with regard to the time spent on the experimental work, then true differences show. The weight titration was performed by a person with little or no training in chemistry and taking half-an-hour, and the volumetric experiment was performed by a person of experience and took an hour. Evidently more experimental work could be accomplished in the ever-shortening practical periods attached to chemistry courses!

B) Percentage of Copper in a Soluble Copper Salt

This determination was based upon the classical redox experiment:

$$Cu^{2+} + e^- \rightleftharpoons Cu^+$$

$$2I^- \rightleftharpoons I_2 + 2e^-$$

$$2S_2O_3^{2-} \rightleftharpoons S_4O_6^{2-} + 2e^-$$

An amount of the copper salt, about 5g, was weighed accurately and dissolved in a weighed amount of water, about 100g, and some sodium thiosulfate, about 7g, were weighed accurately and dissolved in a weighed amount of water, again about 100g. Portions of the copper solution were weighed, about 6-10g, a spatulaful of solid potassium iodide added, and then the released iodine was titrated with the sodium thiosulfate solution to a starch end-point. The titrant was weighed before and after the titration.

From the reaction equations above it can be seen that

$$63.54\text{g Cu} \equiv 248.18\text{g } Na_2S_2O_3\cdot 5H_2O$$

Therefore it follows that if, for example, the solutions contained 5.478g/100g of solution of copper salt and 7.808g/100g of solution of sodium thiosulfate, and W_C and W_N are the weights used of these solutions respectively, then:

$$\%Cu = (63.54/248.18) \times (7.808/100) \times (100/5.478) \times 100 \times (W_N/W_C)$$

This experiment was performed using the solutions prepared with the concentrations as above, and eight titrations yielded a mean value of (25.54 ± 0.20)% with a precision of 7.0ppt, comparing very well with a precision of about 12-15ppt when the experiment was performed volumetrically by a group of students.

Again the speed of this method showed well taking again about half the time that would normally be allocated to such an experiment. The time saved in this case was used by asking the students to develop a titration for the determination of sulfate but using a slightly different end-point indicator.

Determination of the Composition of Dolomite

This experiment is a simple one based upon the reaction of the material ethylenediaminetetra-acetic acid (EDTA) with calcium. EDTA is capable of reacting on a 1:1 molar basis with at least 70% of the metals of the Periodic Table.

The sample of dolomite, about 0.1-0.4g, is weighed accurately and dissolved in the minimum amount of 2M hydrochloric acid with gentle heating. The solution is then made basic, about pH = 10-11, with 2M sodium hydroxide. The pH may be tested using universal indicator paper. Add murexide indicator to the solution and titrate immediately from light pink to purple. Note the weight of titrant used. In this case it might be appropriate to experiment first to see if the 'before' and 'after' colors of the indicator.

$$372.20\text{g } Na_2EDTA.2H_2O \equiv 40.08\text{g Ca} \equiv 100.09\text{g } CaCO_3$$

Let W_S = weight of sample (g)
W_C = weight of calcium carbonate (g)
W_M = weight of magnesium carbonate (g)
W = weight of titrant (g)
Q = concentration of titrant in g EDTA/100g of solution

Therefore: $372.20\text{g } Na_2EDTA{\cdot}2H_2O \equiv 100.09\text{g } CaCO_3$

$W \times Q \equiv W_C$

thus $W_C = (100.09/372.20) \times W \times Q$

and $W_M = W_S - W_C$

For a certain experiment with Q = 1.827g/100g

W_S (g)	W (g)	W_C (g)	W_M (g)
0.104	11.80	0.058	0.046
0.268	29.31	0.144	0.124
0.193	21.57	0.106	0.087
0.397	42.94	0.211	0.186

Based upon these results the average composition of dolomite is:

$$54.4\%\ CaCO_3 + 45.6\%\ MgCO_3$$

From this information it is clear that the composition of dolomite is:

$$CaCO_3.MgCO_3$$

Again this experiment is short enough such that a class of fifteen equipped with a single top-loading balance with a capacity of 160g reading to two or three decimal places can easily finish the experiment in two hours.

Conclusion

All the experiments described take less time than their volumetric counterparts, thus allowing the student to investigate additional problems set by the instructor. These problems may be given to the class en masse on a sheet of paper, or they can take the form of personal suggestions made by the instructor to the student verbally. In either case it is important that the student come to grips with chemical problems experimentally.

Extra questions asked of the students can also be tailored to the abilities of individuals at the discretion of the instructor. Some students work faster than others and it is necessary to hold their interest in some fashion. Their particular questions could take the form of short literature projects based upon readings selected from the primary sources by the instructor which suggest further practical work. For the slower students the extra work may be identical to that of the faster students but should be presented a little more directly, and then reinforced by verbal comments by the instructor.

Finally, the experiments described in the previous section represent only a small number of those possible, and it would be quite possible to design ones for most purposes. For example, some laboratories lack the funds to give students a full practical course, and so experiments perforce have to be inexpensive. For example an experiment using baking soda and white vinegar can be just as illustrative as one using sodium hydroxide and potassium hydrogen phthalate.

Acknowledgments

The author wishes to thank several classes of students who painfully ran the gamut of the experiments and, particularly, Renée Doll and Susan Cassidy who were patient enough to test the method against volumetric analysis for the acid-base titration.

Literature Cited

1. Bishop, E. 1959. High Precision Titrimetry. II. A System of Weight Titrimetric Analysis Using Arbitrary Standards. Anal. Chim. Acta. 20:405-412.
2. Davenport, D.A. 1969. Baby-Bottles and Elementary Chemistry. J. Chem. Ed. 50:629-630.
3. Friedman, H.B. and LaMer, V.K. 1930. An Improved Weight Buret. Ind. Eng. Chem. (Anal. Ed.). 2:54.
4. Gaddis, S. 1959. Titration Without Burets. J. Chem. Ed. 36:290.
5. Guevremont, R. and Kratochvil, B. 1978. Automatic Gravimetric Titration System. Anal. Chem. 50:1945-1948.
6. Kratochvil, B., Findlay, E.J. and Harris, W.E. 1973. A Nonaqueous Gravimetric Titration: Determination of 8-Hydroxyquinoline with p-Toluenesulfonic Acid in Acetonitrile. J. Chem. Ed. 50:629-630.
7. Madsen, E. Rancke. The Development of Titrimetric Analysis till 1806. 1958. G.E.C. Gad, Copenhagen.
8. Seils, C.A., Meyer, R.J. and Larsen, R.P. 1963. Amperometric Titration of Plutonium(VI) with Iron(II). Anal. Chem. 35:1673-1675.
9. Washburn, E.W. 1908. The Theory and Practice of Iodometric Determination of Arsenious Acid. J. Am. Chem. Soc. 30:31-46.

Darwinism in Modern China

Gene Kritsky
Department of Biology
College of Mount St. Joseph
Mount St. Joseph, Ohio 45051

China has a rich philosophical and political history that has been affected by Darwinian evolutionary theory very differently compared to western societies. The Chinese view of creation was never associated with the direct actions of a supernatural being but with the interaction of impersonal forces. The oldest creation story in China was written by Lieh-Tzu who is thought to have lived between 450-375 B.C.E. His creation story is a series of steps in a progression in which the earth and heaven arose from chaos. A century later, Chuang-Tzu elaborated on the progression of life:

> Certain seeds, falling on the water, become duckweed. When they reach the junction of the land and water, they become lichen. Spreading up the bank, they become the dog-tooth violet. . . grafted to an old bamboo which has for a long time put forth no shoots, produces the ch 'ingning which produces the leopard, which produces the horse, which produces man (Veith 1960).

This progressive view of the origin of the universe and of life gives China a very different base from which to receive Darwinian evolutionary theory.

Darwin's views first entered China indirectly via the translated writings of his close friend, Thomas H. Huxley. Yen Fu, a Chinese educator working in England in the late nineteenth century, translated Huxley's *Evolution and Ethics* published in 1896 and published the Chinese version in 1899. His translation had a great impact on Chinese education because he interjected Chinese quotations in place of some of the Western quotations in Huxley's book. This made the translation relevant to Chinese society and allowed Darwin's concepts of natural selection and a struggle for existence to enter China before the translated version of Darwin's *Origin of Species* was published in 1903 (Veith 1960, Freeman, 1977).

Ilza Veith (1960) examined evolution in China as part of the centennial celebration of the publication of the *Origin of Species*. Her study, however, stopped with China before World War II. Since then, China has witnessed turbulent political developments. In 1949, Mao Zedung proclaimed China the Peoples Republic of China and started the country on a Soviet style redevelopment. In 1958, the problems of applying the Soviet approach to China became apparent and Mao initiated the Great Leap Forward. The Cultural Revolution, started in 1966, was an effort to restructure society by tearing down the bureaucracies that had evolved in education, industry, and agriculture. The Cultural Revolution turned the country upside down, closing universities, upsetting industrial development, and disrupting management of the economy. With the death of Mao in 1976, the Cultural Revolution ended and China entered a period of relative stability. The rise of Deng Xiaoping, his rapid program of industrialization and limited experiments with capitalistic motivations led to a reinterpretation of Mao as a great man, credited with bringing the country to communism, but also having made serious mistakes in the last twenty years of his life. This thumbnail sketch of China's history sets the scene for how Darwin and evolution are playing a part in China in the 1980s.

I had the opportunity to visit the Peoples Republic of China in May and June of 1986 as part of a scientific exchange. My visit enabled me to interview scientists, educators, government officials, and students as well as to visit universities, museums, and zoos. I was able to see firsthand how Darwinian evolutionary thought is faring in modern China.

Evolution and darwinism are taught in the compulsory educational system in both nature and history classes. Students I spoke with responded to my questions about Darwin by stating that he was a great man who was important to China because of his role in the development of Marxism. Another student responded with "survival of the fittest" when I mentioned Darwin's name. This linkage of Darwin to Marxism is touted in the Natural History Museum in Beijing, where the exhibit on Darwin and evolution is followed by a display on Marx and Engels. The entrance to the Hall of Man and Human Evolution is flanked by a large oil painting of Mao Zedung and Zhou Enlai greeting the peoples of the world. An interesting cultural aspect was the use of the famous Time-Life evolution of man pictorial which ended with a Chinese rather than a Caucasian.

The exhibit on the history of evolutionary thought in China also included the importance of Thomas Huxley to the introduction of evolutionary theory to China. The exhibit included small photographs of Lamarck, Darwin, and Huxley followed by a larger photograph of Huxley lecturing to a group. The panel also included a painting of Jo Shu Lin, said to be an important Chinese writer on evolution.

The introduction of evolution to school age children was quite obvious even to an outsider. While I was at the Natural History Museum in Beijing, I watched museum guides tour several elementary school groups through the facility. They stopped in the dinosaur hall and like children everywhere they were fascinated with the extinct giants, calling out the names of the various dinosaurs that were pointed out to them. They also stopped in front of the displays pointing out the benefits of evolution as a modern idea of science. The children also toured the human evolution hall and the zoology hall. Indeed, every natural history museum I visited in five Chinese cities had several evolutionary trees to reinforce evolutionary ideas. Even in unusual places you could still find reminders of evolution. Just outside the panda enclosures at the Beijing Zoo, was a series of panels relating humans to the rest of the animal world and the relationship of humans to the evolution of the primates. The primate hall was a distance away from this evolution display which perhaps was placed in that location because of the popularity of pandas making it a widely visited site.

An unexpected use of evolution was to set up a dichotomy between science and religion. One government guide said he would never have Americans tour the Natural History Museum in Shanghai because it would offend us. His reasoning was the museum was organized around evolution and Americans believe in creation. He also claimed that there was freedom of religion in China but that most people were atheists in part due to the discoveries of science.

Evolutionary thought apparently has a role in the new push towards industrialization. The newly renovated dinosaur hall in Beijing has its labels in both Chinese and English, evidently to reinforce the importance of studying English. The lead panel reads:

> Although, at the dawn of human history, people tried to understand living things around them, it is only with the development of modern science and technology that human beings can progressively probe into [the] mystery of ancient and modern organisms. What you will see is only a spot of living things of ancient antiquity, about millions of years ago. However, the invertebrate of all forms, the dinosaurs of varied shapes, the mammals of wide adaptation etc., have extensively supplied us with scientific information concerning morphology, ecology, behavior and evolution of organisms, which can serve the new revolution of science and technology.

Acknowledgments

This project was possible with the support of an Indiana Academy of Science Research Grant and a Summer Research Grant from the College of Mount St. Joseph.

Literature Cited

Freeman, R.B. 1977. The Works of Charles Darwin. Archon Books, The Shoe String Press, Hamden, CT.

Veith, Ilza. 1960. Creation and Evolution in the Far East. In: Evolution after Darwin, vol. III, Issues in Evolution. University of Chicago Press, Chicago. pp. 1-17.

Nature Study: A Practical Science Course for the Non-science Major

Mary Ann Morse
Division of Science Education
Indiana University East
Richmond, Indiana 47374

IU East is a small regional campus of the Indiana University system located in Richmond, Indiana. Enrollment is about 1400 students. Most degrees granted on this campus are at the associate level. Students pursuing baccalaureate degrees do so through Indiana University System schools or through transfer to other IU campuses or other institutions. As in most universities, students at IU East, regardless of major, must fulfill distribution requirements which include some hours in the field of science.

On a campus with limited number of faculty and course offerings, providing science courses appropriate for the non-science major can be a problem. A first-level course designed as groundwork for majors in a particular discipline, may not satisfy the long-term goal of scientific literacy for a student in a non-science area. For several years we have offerd at IU East a course for non-science majors titled Natural History (Plant Sciences B214). Feeling further description necessary, it is listed in the schedule of classes with the explanation, "a course in nature study". The 3 credit hour course may be used to fulfill science requirements in most IU East programs, but does not count toward a Biology major in the IU system.

Natural History attracts students from many major areas. Bachelor of General Studies students usually make up the greatest number, with Business, English, Criminal Justice, Education, and Human Services well represented.

The course is offered each summer for one six-week session, usually from early July to mid-August. It meets two mornings a week from 8:15 to 11:40. This time is sufficient to allow travel off-campus for field trips, and is early enough to avoid the heat and possible thunderstorms of a later summer day. All class sessions involve outdoor activities; some days we are not indoors at all.

The scope of a course titled Natural History might include many topics. Instead of focusing on content in a particular area, emphasis is placed on techniques of nature study. Since I am a biologist, I then use living things as a vehicle for teaching how to study in the out-of-doors. In this way students come from the course, not with a volume of facts which may be soon forgotten, but with tools which can be used to increase their enjoyment of the world around them. The texts for the course are *Insects*, and *Pond Life* (Golden Nature Guides) (2,4).

Typical enrollment is 20 to 24 students. Handling this many people in an activity-based course is a problem. The nature hike approach simply does not work. A major challenge in planning has been to devise activities which can be done by small groups with little or no guidance. I make extensive use of a series of Discovery Worksheets which were originally developed for Indianapolis Public Schools and their Bradford Woods outdoor program (1). These materials provide many activities geared for individuals or small groups. It is not always possible to work in small groups. In moving to a study area we often go as an entire class. It is interesting how these mass walks change as the course progresses. At the beginning they go quickly, with quite a bit of chatter among students; at the end it is difficult to move a group along on schedule because individuals are so often stopping to investigate things, not only asking me questions, but sharing with classmates. After completing activities in a study area discovery sheets are used on an individual basis as we return to classroom or cars. Drawing with natural materials, sketching, listening—quiet, reflective exercises are used at these times.

Early emphasis is on sharpening senses and improving observation skills. One favorite tool for focusing observations is the cinquain—a simple written form which forces the author to become involved with his subject (Figure 1). We write several cinquains during the summer. Closer observation using dissecting microscopes is always a treat. Students are admitted to a world they have never seen before as they focus downward through a clump of moss or into a flower.

CINQUAIN: WORKSHEET

____
1 word

__________ __________
2 descriptive words

__________ __________ __________
3 action words

__________ __________ __________ __________
4 words tell how one feels about it

____
sum up with a word related to the first
or related to the whole study

FIGURE 1. The Cinquain.

Values are an important part of the course. Because for some students the out-of-doors is unfamiliar, there are usually some negative feelings—especially about such things as snakes, slugs, and spiders. As we learn about these things, attitudes mellow. "YUCK" is not allowed. I use another writing exercise, the diamond, to direct students to see positive and negative aspects of a subject (Figure 2). After the first "yuck" of the session, this form is taught, and subsequent "yuckers" are assigned a diamond to appear on the board before the next class. I have had some students actually do library research to find out positive information about their topics (mosquitoes, in particular).

Woven into the outdoor structure of the course is a study of plants and animals, their characteristics, needs, roles in nature and some classification (Figure 3). For example, as part of plant study I introduce keys by using the key from *Fifty Trees of Indiana* (31). First, branches are brought into the classroom for practice, then students working in small groups, key additional trees found on the IU East campus. We capture insects and other arthropods and discuss features which characterize major insect orders and

RAIN

WET DRIPPING

HELPS CROPS GROW

A BLESSING / A NIGHTMARE

MUDDY RAIN PUDDLES

CAUSES DAMAGE

FLOODS

Figure 2. The Diamond.

which separate insects from their relatives. Each outdoor experience integrates subject matter and techniques.

Many activities are done without leaving campus. At least once during the summer, each student is required to provide something for "show and tell". Often this allows us to discuss things which students have questions about and find interesting which were not necessarily on the schedule or found during our outdoor class sessions. The IU East campus provides a good outdoor laboratory. There are two wooded nature trails with intermittent streams, and a parcourse trail which goes through meadow and scrubby areas. Late in the course students are asked to bring children to class with them. We usually have about 30-40 children in attendance. Working in paris, the nature study students guide small groups of children through discovery activities on the IU East campus. Guiding another person's discoveries involves a different perspective for the students. Though many are apprehensive about the day, at its completion most agree it was a valuable experience.

July 8	Getting into nature, describing, using senses	(IUE)
July 10	Plants and their role, trees, using keys	(IUE)
July 15	Higher plants-some important groups, looking closer	(IUE)
July 17	Lower plant classification, plant reproduction	(Sedgwick's Rock)
July 22	*Quiz*; Animal classification-invertebrates, insects	(IUE)
July 24	The pond community	(Hayes Arboretum)
July 29	Birds, mammals, interdependence	(IUE)
July 31	*Quiz*; Discovery in an urban setting	(Joseph Moore Museum, Promenade)
Aug 5	Geologic history	(Whitewater Gorge area)
Aug 7	Discovery through children's eyes	(IUE)
Aug 12	Canoe trip	(Brookville, IN)
Aug 14	Final activity (quiz)-*YOU* teach the course	

Figure 3. Schedule of Activities from Course Syllabus.

Field trips off campus are restricted to the local area since student cars must be used for transportation. We go first to Sedgwick's Rock Nature Preserve where we wade up a creek to an area where we study lower plants. A trip to Hayes Arboretum provides 2 ponds in which to dip our nets to study ecological relationships within a community. This is followed by a comparison to meadow and forest communities explored on our campus. At the Joseph Moore Museum on the Earlham College campus we study animals not encountered in the field. This trip prompts discussion of nature study in an urban situation, and is followed by a discovery session on Richmond's downtown promenade shopping area. The last activity of the summer (and most popular) is a morning of canoeing on the Whitewater River. We rent canoes and spend about 4 hours on the river with stops along the way for discussion, food, and rest.

Attendance and participation are primary factors in evaluating student performance in the course. In addition three quizzes are given which cover classroom presentations, as well as questions requiring some thought about experiences on field trips—"What was your favorite thing about. . . ? What specific ways did you use each of your five senses on the . . . trip"? For the final quiz, students are taken to a new area and each pair given 50 feet of twine. They are instructed to lay out a nature trail in a designated area and conduct an 8-station nature hike for their classmates.

Formal evaluation of the course is done on the day of the final quiz. A form is used which asks student reaction to specific activities during the summer, both on and off campus. This has been a most useful tool in planning. The most satisfying form of evaluation, though, is an observation of behavior change as the summer progresses and student reactions during the course. There are a few comments which are consistently made from year to year: ". . . made learning fun". "In all my time outdoors, I never really saw things before; now I point things out to others". "I'll never look at my surroundings quite the same again". If a goal of education is to bring about a behavior change in the learner, then Natural History (B214) at Indiana University East is real education.

Literature Cited

1. Hart, John W., Jessie M. Turner and Magdalene A. Davis. 1977. *Discovery Worksheet Series.* Indianapolis Public Schools. Indianapolis, IN.
2. Reid, George K. 1967. *Pond Life.* Golden Guide Series. Western Publishing Company. New York, NY.
3. Shaw, T.E. 1968. *Fifty Trees of Indiana.* Division of Forestry, Department of Natural Resources, Indiana and the Department of Forestry and Conservation, Purdue University, West Lafayette, IN.
4. Zim, Herbert S. and Clarence A. Cottam. 1951. *Insects.* Golden Guide Series. Western Publishing Company. New York, NY.

SOIL AND ATMOSPHERIC SCIENCES

Chair: John T. Curran
National Weather Service
Indianapolis International Airport
P.O. Box 51256
Indianapolis, Indiana 46251 (317) 248-4042

Chair-Elect: Eldon L. Hood
Department of Agronomy
Purdue University
West Lafayette, Indiana 47907 (317) 494-4788

ABSTRACTS

The Relationship Between Cl and SO_4 Particulate Concentrations and Air Masses. Richard H. Grant and William W. McFee, Department of Agronomy, Purdue University, West Lafayette, Indiana 47907.——A study to describe the particulate characteristics of the surface layer of the atmosphere over a region of southwest Indiana was conducted. The particulate size distribution (mass median diameters (MMD) of 7, 3.3, 2, 1.1 μm and less than 1.1 μm) of sulfate and chlorine anions are determined for thirty-nine 24-hour periods between September 1985 and April 1986.

Results indicate that: 1) high concentrations of chlorine in large particles (MMD greater than or equal to 3.3 μm) correspond with southerly winds of maritime tropical air-mass air, 2) low concentrations of chlorine in large particles correspond with westerly winds of continental air-mass air, 3) high concentrations of sulfate in giant particles (MMD 7 μm) correspond with both synoptic situations but the maritime tropical air-mass air had higher concentrations of both giant particle and small particle (MMD $<$ 1.1 μm) sulfate than the continental air-mass air at the site of measurement. It was concluded that the large particle sulfate and chlorine was at least partially due to sea salt particles from the maritime air mass.

Construction of Highway Embankments over Amorphous Peats and Mucks. C.W. Lovell and Timothy Crowl, Purdue University, West Lafayette, Indiana 47907.——There are a large number of deposits of amorphous peat and muck scattered across the State of Indiana. Highway embankments constructed over these materials have experienced large settlements over extended periods of time, resulting in excessive distress to the roadways. This paper focuses on the development of a laboratory procedure to be used in the design of highway embankments across such materials to minimize settlement during their service lives.

The procedure has been identified on the assumption that embankments will be constructed using staged loading methods, allowing a majority of the settlement to occur during construction. Laboratory tests performed on samples produced from a thoroughly remolded slurry will be used for design. K_0 triaxial tests will be performed to determine the failure envelope of the materials. Creep tests will be run at stress levels that will simulate the staged loading of the foundation materials to determine the coefficient of secondary compression for use in a settlement prediction model.

During subsequent embankment construction the failure envelope will be used to determine the magnitude of load that can be applied without shearing the foundation material. The duration of each load will be determined from the settlement prediction model.

Acid Sulfate Soils of the Mangrove Swamps of Rivers State, Nigeria

E.M. Ossom, N.O. Isirimah, A.G. Ojanuga and C.L. Rhykerd
Faculty of Agriculture
University of Science and Technology
P.M.B. 5080, Port Harcourt, Nigeria
and
Department of Agronomy
Purdue University
West Lafayette, Indiana 47907

Introduction

The mangrove swamps of southern Nigeria form the transition zone between the coastal waters bordering Nigeria to the south and the forested fresh-water swamps to the north. The quality and quantity of the forest products (e.g. timber, fibers, etc.) of southern Nigeria are affected by the ecology of the mangrove swamps with specific reference to the physical and chemical properties of the soils. The mangrove soils and wetland soils are probably comparable in general structure and outlay with the wetlands of the Mississippi delta or those of the Ganges delta in India.

The soils of the mangrove swamp of southern Nigeria have only been studied in recent years. The neglect of their study prior to recent times was probably because navigation through the creeks and channels is a risky and difficult undertaking as sandbars make navigation difficult, and salt water crocodiles (*Crocodylus prosus*) abound. Recently, ecologists with determination and seriousness of purpose, have ventured to study the mangrove swamps, their management and potential uses.

Materials and Methods

Soils of the tidal brackish-water swamps and salt-water tidal mangrove swamps were investigated. The sites of investigations were the mangrove swamps of Brass (4°42′ N, 6°17′ E) and Degema (4°45′ N, 6°47′ E) all in the Niger Delta. The annual rainfall at Degema is about 2,022mm and the mean annual temperature is about 26°C; Brass has an annual rainfall of 3,120mm. Pedons representative of different soil types were dug, described and analyzed. Because of the need to retain the natural state of the soils and to prevent oxidation during transportation, each sample was collected in a black polyethylene bag. In the laboratory, a subsample of each soil sample was taken for pH determination in the wet state while another subsample was air-dried for about 15 days. The dried subsample was gently crushed in a mortar and sieved with a 2-mm sieve. Particles retained on the seive were discarded while those which passed through were used for the following analyses: particle size—by the modified hydrometer method (9); pH in water and $CaCl_2$ using the glass electrode pH meter; total nitrogen by the microkjeldahl method; total organic carbon by the Walkey Black oxidation method as described by Allison (1) and chemical analysis of total water soluble elements, exchangeable cations, free or reactive ions and structurally bound elements determined sequentially by the modified methods of Khalid (5) and Chao and Zhou (4).

Results and Discussion

Within the mangrove tidal wetlands are presently recognized and classified Histosols including Sapric Tropohemists, Typic Sulfihemists and (Fibric) Sulfihemists (12).

Soil Morphology

It was observed that in both the tidal brackish-water and tidal salt-water mangrove swamps, the soils were fibrous, spongy peats undergoing different stages of development. They were also composed of soft mangrove fibers easily destroyed by rubbing between the thumb and fingers. Hemists and Fibrists were common peats while Saprists appeared restricted to the elevated edge of tidal flats with fresh mud regularly deposited by tidal or flood water. The surface horizon of the peats was fibric while the subsurface horizon included varied proportions of fibric, hemic and hemic with some sapric material. No clear pattern of mineral matter entrapped by the mangrove roots was established.

Water Holding Capacity of Mangrove Soils

The peats were sandy clay loam in texture. The water saturation varied from 36-70% and was related to the total organic matter content of the soils. The total organic matter of the soils varied from 10-54% (Table 1). Table 2 shows some chemical characteristics of mangrove soils. The amount of humified matter was low, varying from 1.83-4.65% and suggesting a low rate of humification of organic material under the prevailing anaerobic conditions. Soils of the salt water swamps had the largest amount of total organic matter. Probably, the large amounts of excess salts in the latter soils prevent microbial activity and expected mineralization of organic matter.

Table 1. Physical characteristics of mangrove swamp soils in Nigeria.

Environment	Location (Pedon)	Horizon & Depth (cm)	Water Saturation %	Total Organic Matter, %	Soil Classification
Tidal	Oboibiri,	00-20	66.0	n.a.	Sapric
brackish water	Brass	20-40	54.8	26.1	Tropohemist
mangrove swamp		40-70	n.a.	28.1	
	Sabatoru,	00-15	48.2	20.9	Sapric
	Nembe	15-30	36.6	12.7	Sulfihemist
		30-60	36.0	10.0	
	Ogonokun	00-25	n.a.	n.a.	Typic
	near Degema	50-75	n.a.	22.9	Sulfihemist
		75-100	n.a.	26.4	
Tidal	Nembe	00-30	38.7	n.a.	Fibric
salt water	Creek	30-50	42.5	23.3	Sulfihemist
mangrove swamp	Site 3	50-80	39.6	23.7	
	Nembe	00-25	51.5	31.6	Typic
	Creek	25-35	70.4	54.2	Sulfihemist
	Site 1	35-50	65.0	49.5	
		50-70	58.3	n.a.	

n.a. = Data not available

Soil pH

In the wet state, soil pH was between 4.7 and 7.0 but on drying soil pH dropped drastically to less than 4.0 in most soils (Table 2). This drop in pH showed that the peat soils have a tendency to develop extreme acidity on oxidation owing to the presence of sulfidic or pyritic materials capable of releasing appreciable amounts of sulfuric acid through chemical or biological oxidation (3,10). The pungent odor usually emanated from the mangrove swamp soils originates from the release of hydrogen sulphide under anaerobic conditions.

Macronutrient Status of Soils

Total N was relatively higher than in the non-organic or well-drained soils of the same environment.

Table 2. Chemical characteristics of mangrove swamp soils in Nigeria.

Profile	Depth	pH		Total N	Organic C	Avail. P	
(Pedon)	(cm)	Wet	Dry	%	%	(ppm)	E S P
	Sapric Tropohemist						
1	00-20	5.1	4.6	0.12	4.03	n.a.	10.7
	20-40	5.3	4.2	0.34	4.04	2.8	16.5
	40-70	4.7	4.0	0.31	4.05	n.a.	6.6
	Typic Sulfihemist (Saline phase)						
2	00-15	6.2	3.1	0.24	3.71	1.6	6.0
	15-30	6.0	3.1	0.08	2.32	1.8	11.4
	30-60	6.8	3.6	0.07	1.93	2.4	14.2
	Typic Sulfihemist (Saline-sodic phase)						
3	00-30	5.5	2.7	0.29	3.82	2.3	57.7
	30-60	6.7	3.4	0.07	2.69	2.3	39.8
	60-90	7.0	4.7	0.06	1.83	n.a.	40.9
	(Fibric) Sulfihemist (saline-sodic phase)						
4	00-30	5.5	2.0	0.35	4.34	3.4	21.2
	30-50	5.5	2.5	0.31	4.43	n.a.	23.7
	50-90	6.2	4.0	0.71	4.65	n.a.	35.2
	(Sapric) Sulfihemist (saline-sodic phase)						
5	00-25	6.1	3.4	0.35	3.95	2.0	26.2
	25-35	5.0	1.9	0.34	4.08	n.a.	n.a.
	35-50	5.9	2.3	0.40	4.28	n.a.	39.6
	50-90	5.0	2.5	0.28	4.14	n.a.	n.a.

ESP = Exchangeable Sodium Percentage
n.a. = Data not available

The range of 0.06-0.71% indicated the high N supplying potential of the mangrove swamp soils. Available P was quite low, in the range of 1.6-3.4 ppm. Water soluble Mg (Table 3) was the highest (101 ppm) among the macronutrients while P was the lowest (9 ppm). About 19% total sulfur was detected in these soils. Among the exchangeable cations, K was the lowest while Mg was the highest. The structurally bound concentrations of the macronutrients were in the order of P > Mg > K > Ca while the reactive mobile ions were in the order of P > Mg > Ca > K. These results were in agreement

Table 3. Elemental ions - constituents of surface soils of the mangrove swamps in Nigeria.

Element	Water Soluble (ppm)	Exchangeable Cations (ppm)	Structurally Bound Crystalline (ppm)	Reactive Mobile Ions (ppm)
P	9	7	295	25
K	10	2	29	1
Ca	37	18	3	9
Mg	101	43	62	11
Al	68	21	34,165	692
Fe	699	88	16,785	685
Mn	9	3	96	3
Si	403	28	206	133

with those of Sposito (13) who reported that relatively higher amounts of macro-solute metal ions appeared to be present in organic soils of brackish-water swamps.

The exchangeable sodium percentage (ESP) ranged from 6.0-57.7 (Table 2). The presence of appreciable amounts of Na on the exchange site was indicative of the presence of sulfates and carbonates of sodium active in alkaline hydrolysis.

Other Nutrients

The concentration of both water soluble and exchangeable cations followed the same trend and was in the order of Fe > Si > Al > Mn. Similarly, the structurally bound (crystalline) and reactive mobile ions both followed the same trend in the order of Al > Fe > Si > Mn. The results were consistent with earlier observations of Schwertmann (11), Nordstrom (7) and Chao and Zhou (4) who reported that two dominant elements in mobile reaction state in wetland soil suspension (1:9 soil water) were Al and Fe existing possibly as free oxyhydrates or organometal complexes. The high amounts of structurally bound Al and Fe indicated the presence of alumino silicates which could be weathered readily to release the elements.

The presence of S and Fe appeared to be a factor in the development of potential acid sulfate property in the mangrove swamp soils.

Agricultural Implications

The need for the reclamation of the mangrove swamp soils had been earlier advocated and their potentialities highlighted (2,8). If the fresh water mangrove swamps are reclaimed and the soils amended, it is possible to use them for improved fishery and for the cultivation of such crops as swamp rice, pineapples, cassava, water yams and vegetables. Cash crops such as oil-palm and coconut can be grown also. Forestry products can be obtained from the mangrove swamps if the potentials of *Nypa fruticans*, *Raphia* species and *Alchornea cordifolia* are adequately exploited.

However, other than the huge cost of reclamation of the soils, several management problems have to be solved. The greatest of these is ion toxicity (to plants) arising primarily from a high level of exchangeable Al. Excess soluble salts as well as the Ca/Mg imbalance would also present a major problem. Extreme acidity non-conducive to good plant growth is bound to develop on exposure of the soils to oxidation which must be countered by soil management, often an expensive venture in this regard. The problem of alkaline hydrolysis may result in soil dispersion and creation of unfavorable soil structure. Subsidence of the peat soils on rapid weathering following exposure and due to their conversion from fibric to sapric state will have to be contended with.

In using the mangrove swamps for forestry and agricultural purposes, it should be stressed that plant adaptation must be the guiding principle. Some plants are known to have the ability to grow in soils which contain levels of toxic ions lethal to other species. Those species which resist ion toxicity are found to use one or a combination of four mechanisms: tolerance, phenological escape, exclusion and amelioration. The swamp rice plant, for example, has been observed to oxidize Fe^{2+} to Fe^{3+} by oxygen excretion (a type of phenological escape by direct environmental modification) from the roots, so avoiding Fe^{2+} toxicity (14). Tal (15) observed that cultivated tomatoes (*Lycopersicon esculentum*) absorbed less Na^+ and Cl^- when grown under high salinity than the wild *L. peruvianum*, with adverse effects on both relative water content and growth rate. *Avicenia africana* (white mangrove) and *A. nitida* reduce salt concentration by excretion while *Rhizophora racemosa* (red mangrove) reduces it by exclusion (6). To lessen the problems of ionic toxicity in the mangrove swamp soils, other than drainage and liming, flood protection measures and control of water table will be needed.

Conclusion

Despite the high levels of toxic ions and high potential acidity in the mangrove swamp soils, their high water holding capacity, nutrient levels and organic matter contents suggest that these soils can be used for agricultural, forestry and fishery purposes if increased classification and characterization work and massive investments are made for land reclamation and soil amendments, using improved planting material including adaptive species.

Literature Cited

1. Allison, L.E. 1965. Organic carbon. In "Methods of Soil Analysis". CA. Black (ed.). Amer. Soc. Agron. Inc., Madison, Wisc. pp. 1367-78.
2. Bloomfield, C., and A.B. Zahari. 1982. Acid sulfate soils. Outlook on Agric., Vol. II (2): 48-54.
3. Brinkman, R., and L. Pons. 1973. Recognition and prediction of acid sulfate soil conditions. In Proc. of International Symposium on Acid Sulfate Soils, 13-20 August 1972. Wageningen Publication No. 18, Volume 1.
4. Chao, T.T., and L. Zhou. 1983. Extraction technique for selective dissolution of cemorphous iron oxides from soils and sediments. Soil Sci. Soc. Amer. J. 47:225-232.
5. Khalid, R.A., W.H. Patrick, Jr. and R.P. Gambia. 1978. Effects of dissolved oxygen and chemical transformations of heavy metals, phosphorus and nitrogen in an estuarine sediment. Estuarine and Coastal Marine Science, 6:21-35.
6. Lear, R., and T. Turner. 1977. Mangroves of Australia. University of Queensland Press, p. 84.
7. Nordstorm, D.K. 1982. Aqueous pyrite oxidation and the consequent formation of secondary iron minerals. SSSA Special Publication No. 10. Acid Sulfate Weathering P. 37-56.
8. Ossom, E.M., and C.L. Rhykerd. 1986. The mangrove swamps of southern Nigeria II. Problems and Prospects. Proc. Ind. Acad. Sci. 95 (In press).
9. Patrick, W.H. Jr. 1958. Modification of method of particle size analysis. Soil Sci. Soc. of Amer. Proc. Vol. 22(4): 336-7.
10. Poon, Y.C., and A.B. Bloomfield. 1977. The amelioration of acid sulfate soil with respect to oil-palm. Trop. Agric. 54:289-305.
11. Schwertmann, U. 1979. Is there amorphous iron oxide in soils? Abstract. Ann. Mtg. Soil Sci. Soc. Am., Ft. Collins, CO.
12. Soil Survey Staff. 1975. Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. Soil Conservation Service, USDA Agriculture Handbook No. 436.
13. Sposito, G. 1977. Soil Chemistry. McGraw Hill Yearbook, Science and Technology. McGraw Hill Book Co., Inc. 8 p.
14. Tadano, T. 1975. Devices of rice roots to tolerate high iron concentrations in the growth media. Jap. Agric. Res. Quart. 9:34-39.
15. Tal, M. 1971. Salt tolerance in the wild relatives of the cultivated tomato: response of *Lycopersicon esculentum L. peruvianum* and *L. esculentum minor* to sodium chloride solutions. Aust. J. Agric. Res. 22:631-638.

A Polar Area Index Methodology for Forecasting Hemispheric Surface Temperature Trends

ALBERT PETERLIN AND JAMES R. MCINTYRE
NOAA, National Weather Service
Purdue University
West Lafayette, Indiana 47907
AND
KENNETH L. SCHEERINGA AND JAMES E. NEWMAN
Department of Agronomy
Purdue University
West Lafayette, Indiana 47907

Introduction

Angell and Korshover (1977A,B; 1978A,B,C) published a series of papers on expansion and contraction of the arctic air pool about the polar vortex after calculating the area enclosed within a specified isopleth on a seasonal 300 mb chart. Mean seasonal values denoting expansion and contraction were presented. The magnitude of the area enclosed within the contour was shown to be an effective reflection of the Northern Hemispheric surface temperature.

To be operationally significant and useful, an area index representative of the cool air reservoir and its seasonal expansion or contraction needs to be computed far more frequently than once each season. The chart used would have to be routinely available to the forecaster. Peterlin (1981) developed a circumpolar area index using the 5640 meter isoheight line on the 500mb Northern Hemispheric analysis. This constant pressure surface depiction is produced by the National Weather Service in a fully automated procedure at 000Z and 1200Z daily. The polar stereographic projection is on a scale of 1 to 40 million on which geopotential height intervals are drawn with a spacing of 60 meters (Figure 1).

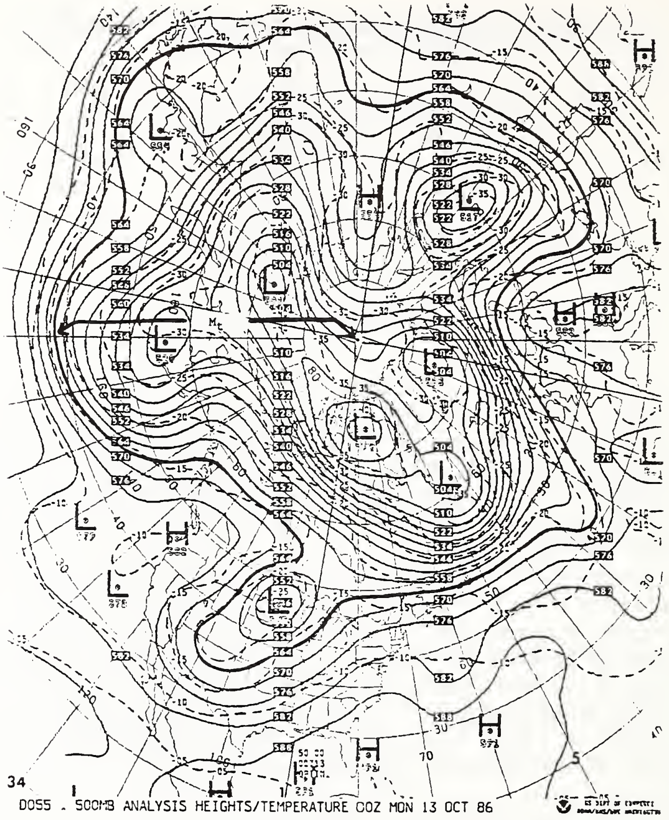
The objective of this paper is to demonstrate some techniques and procedures to regionalize and geographically define a surface hemispheric temperature forecast.

Data, Procedures, and Results

Index values were computed on fixed dates at weekly intervals by measuring the length of the axis from the pole to the 5640-meter isoheight line along each 10° longitude as illustrated in Figure 1. Fixed dates were chosen to correspond with the beginning of each climatological week except that the week beginning January 3 is numbered 1 rather than the week beginning March 1.

Because of map size distortion, index values are adjusted to an adopted 1972 standard based on a comparison of the length of the 60°W meridian from 20°N to 30°N latitude. The index value for each date is simply the summation of the 36 meridional lengths from the pole to the 5640-meter isoheight line. These index values represent the area enclosed within the 5640-meter isoheight line.

A plot of these indices by week displays a sinusoidal tendency. An example for one sample year (1972) is shown in Figure 2. Index values reach a minimum in summer (week 30 in 1972) and a maximum in the winter (week 6 in 1972). With ten years of weekly index calculations (1972-1981), weekly means were calculated as "normal" to allow synoptic comparison (Table 2). By measuring current vortex size each week and comparing it to its normal, the relative size of the cool air pool and its anomaly within the annual cycle of change can be quantified.



$$A_i = \sum_{t=1}^{36} M_t$$

FIGURE 1. 500mb analysis with indexing technique highlighted. 5640-meter contour darkened.

TABLE 1. Fixed dates on which index values were computed.

week	date	week	date	week	date	week	date
1	Jan 3	14	Apr 5	27	Jul 5	40	Oct 4
2	Jan 10	15	Apr 12	28	Jul 12	41	Oct 11
3	Jan 17	16	Apr 19	29	Jul 19	42	Oct 18
4	Jan 24	17	Apr 26	30	Jul 26	43	Oct 25
5	Jan 31	18	May 3	31	Aug 2	44	Nov 1
6	Feb 7	19	May 10	32	Aug 9	45	Nov 8
7	Feb 14	20	May 17	33	Aug 16	46	Nov 15
8	Feb 21	21	May 24	34	Aug 23	47	Nov 22
9	Mar 1	22	May 31	35	Aug 30	48	Nov 29
10	Mar 8	23	Jun 7	36	Sep 6	49	Dec 6
11	Mar 15	24	Jun 14	37	Sep 13	50	Dec 13
12	Mar 22	25	Jun 21	38	Sep 20	51	Dec 20
13	Mar 29	26	Jun 28	39	Sep 27	52	Dec 27

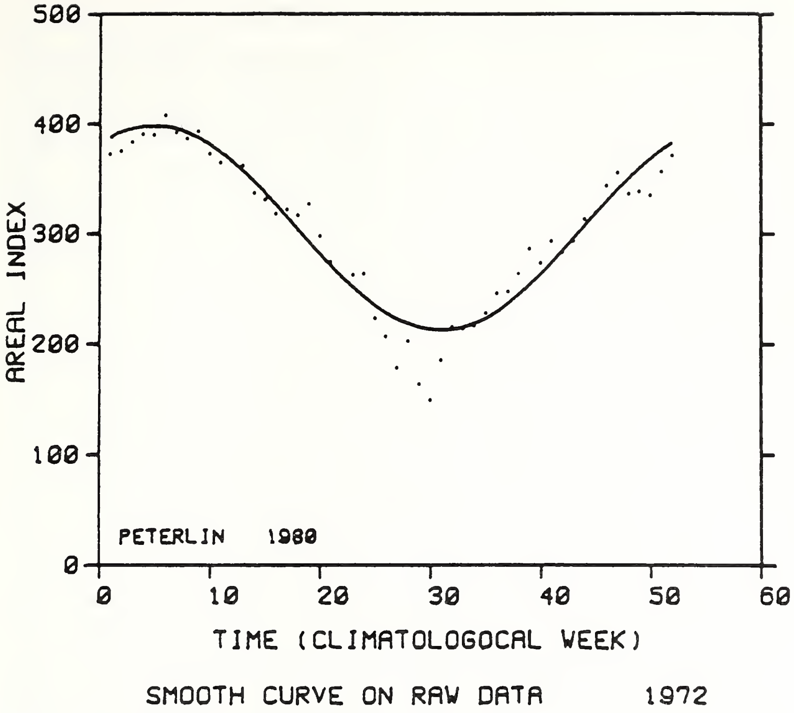


FIGURE 2. 1972 raw data plot superimposed upon first harmonic fit.

The weekly indices for each year were smoothed by fitting the first harmonic on time (week).

$$Y_t = a_0 + A \cos (ct - \Theta)$$

where Y_t is the index value for week t ($t = 0, 1, 2. . .5$); a_0 is the average of the 52 indices (Y); A is the amplitude or half the range from the maximum to minimum Y. The constant $C = 2\pi/52$ converts the numbered weeks to angular measure in radians and Θ is the phase angle or time of the maximum Y. To estimate the constants from the observed Y_t value, the equation was rewritten:

$$Y_t = a_0 + a_1 \cos(ct) + b_1 \sin(ct)$$

where $A = \sqrt{a_1^2 + b_1^2}$ and $\tan \Theta = b_1/a_1$. The coefficients a_0, a_1, and a_2 were estimated by the method of least squares. Smoothed 1972 data is superimposed on the 1972 raw data plots in Figure 2. Ten year means (normals) were also fit and are used as the basis for comparison in Figure 3. The area plot is essentially bimodal. Yearly subsets are either expansional or contractional rather than being defined by the more traditional seasons. The contractional regime begins about week 7 (February 14) and ends about week 29 (July 19). The expansional regime begins week 29 (July 19) and continues to week 7 (February 14).

First harmonic smoothing offers forecast potential through the use of persistence. Persistence is still one of the most useful forecasting tools available to the operational

TABLE 2. Raw index values and 10 year mean as "NORMAL".

Week	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	NRML
1	376	356	373	359	365	383	377	375	391	377	372
2	378	406	400	381	354	389	382	369	395	370	381
3	387	400	384	376	368	399	394	383	387	373	383
4	394	370	371	379	375	396	384	387	387	384	383
5	396	352	394	375	382	390	396	394	391	376	383
6	411	375	375	398	384	384	398	382	388	375	386
7	396	381	387	396	379	369	402	371	397	377	387
8	390	370	360	384	380	369	381	380	397	377	380
9	396	382	360	382	373	368	400	384	376	391	380
10	376	372	377	389	383	345	383	368	379	361	372
11	368	368	375	373	377	357	365	369	362	377	369
12	369	362	348	379	368	353	367	364	372	379	367
13	365	363	375	367	349	352	355	353	357	364	359
14	339	363	357	352	352	339	354	350	348	327	349
15	334	381	352	338	348	327	349	347	340	339	344
16	321	355	340	327	331	323	354	334	324	320	334
17	325	348	334	312	328	324	348	307	318	324	327
18	320	325	340	309	325	305	311	320	323	301	317
19	330	301	317	302	303	305	297	301	318	297	307
20	301	301	305	295	291	293	294	281	285	288	293
21	278	286	310	277	283	283	301	283	283	376	287
22	264	299	302	275	287	258	276	255	278	277	276
23	266	255	280	287	250	262	262	255	244	277	266
24	267	260	240	257	267	232	253	247	240	261	253
25	227	222	234	233	238	237	246	232	233	222	235
26	211	222	244	184	174	241	215	219	216	206	216
27	182	215	223	176	233	184	218	180	230	202	208
28	207	217	199	192	213	159	180	216	219	208	200
29	164	203	213	157	217	204	210	191	211	190	189
30	152	205	171	206	217	209	212	193	194	191	193
31	189	218	185	190	192	176	202	200	198	183	197
32	219	184	200	194	189	217	222	228	192	161	203
33	217	204	215	232	213	196	241	197	196	190	211
34	220	198	239	239	209	229	222	226	198	202	216
35	231	239	232	238	244	247	248	238	225	205	233
36	249	252	261	237	241	238	275	231	253	231	246
37	250	235	246	247	244	235	257	270	251	254	250
38	267	280	260	251	258	254	255	258	265	280	263
39	289	271	276	269	288	268	275	267	283	270	275
40	276	252	267	279	295	273	283	290	293	280	280
41	296	290	287	287	301	295	275	292	281	301	288
42	286	301	295	306	305	303	299	283	311	289	296
43	297	300	291	305	334	299	298	306	315	289	302
44	316	325	326	312	318	309	296	325	318	306	315
45	322	322	321	321	322	312	299	311	339	305	320
46	346	331	322	335	341	316	328	317	330	331	333
47	358	336	341	340	348	355	330	315	338	344	341
48	339	341	358	359	347	348	353	334	344	348	347
49	341	357	369	338	359	370	347	326	351	352	350
50	337	359	364	368	359	354	344	360	354	363	357
51	359	368	362	349	388	379	364	378	360	372	366
52	374	359	353	360	403	363	377	372	359	378	371

meteorologist. By fitting the first harmonic to the immediate 17 weeks of actual raw index values, the output, assuming persistence, becomes the forecast product.

The 1982 forecast plot in Figure 3 displays the warm hemispheric winter weeks and the cool but near normal transitional spring season (actual data). The forecast period

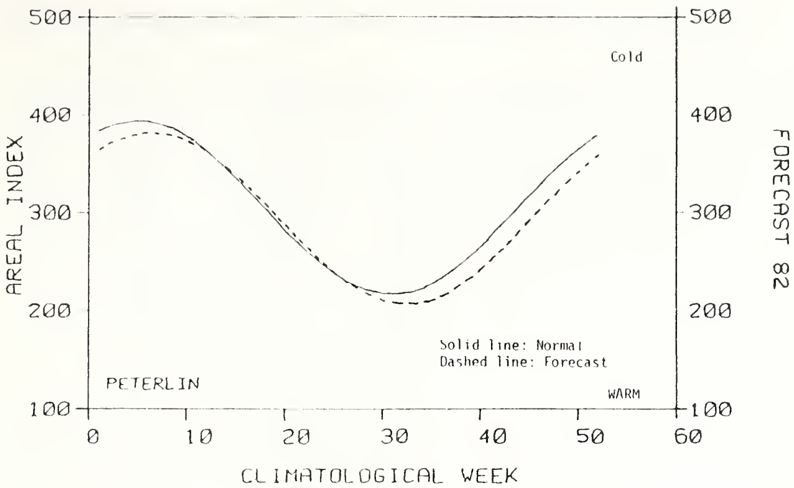


FIGURE 3. First harmonic normal superimposed upon smooth forecast plot.

called for a warmer than normal hemispheric summer with crossover about week 23 (June 7). The warm contracted pattern is maintained through the fall (Figure 3).

The timing of expansional or contractual momentum and trend development of the raw mean data is highlighted by the week to week differences in Table 3. Trend reversal is evident from week 7 (Feb. 4) to 8 (Feb. 21) and week 29 (July 19) to 30 (July 26). Week to week differences can highlight trend definition and acceleration of the differential may be an indication of momentum. Five week mean index values were also computed on traditional seasonal dates. These mean indices are shown in Table 4.

Mean winter index values were greatest in 1972, 1978, and 1980. Mean values 1973 to 1976 were declining or stable with trend reversal in 1976. This pattern is associated with the extreme winter that occurred in much of the continental United States in 1976-77. Index values during the winter years 1977-1978 were larger than values calculated for the years 1973 to 1976.

TABLE 3. Raw normal week to week area index differential.

Weeks	Diff	Weeks	Diff	Weeks	Diff	Weeks	Diff
52 1	+1	13 14	−10	26 27	−8	39 40	+5
1 2	+9	14 15	−5	27 28	−8	40 41	+8
2 3	0	15 16	10	28 29	−11	41 42	+8
3 4	0	16 17	−7	29 30	+4	42 43	+8
4 5	0	17 18	−10	30 31	+4	43 44	+13
5 6	+3	18 19	−10	31 32	+6	44 45	+5
6 7	+1	19 20	−14	32 33	+8	45 46	+13
7 8	−7	20 21	−6	33 34	+5	46 47	+8
8 9	0	21 22	−11	34 35	+17	47 48	+6
9 10	−8	22 23	−10	35 36	+13	48 49	+3
10 11	−3	23 24	−13	36 37	+4	49 50	+7
11 12	−2	24 25	−18	37 38	+13	50 51	+9
12 13	−8	25 26	−19	38 39	+12	51 52	+5

TABLE 4. Five week mean area index values centered on indicated seasonally definitive date and year.

Year	Jan 31	May 3	Aug 2	Nov 1
1972	396.8	319.4	188.2	313.4
1973	375.6	326.0	202.8	336.0
1974	382.2	327.2	196.8	311.0
1975	384.8	309.0	195.8	315.8
1976	377.6	315.6	205.6	324.0
1977	387.6	310.0	200.4	307.8
1978	394.8	320.8	217.4	304.0
1979	383.4	308.6	201.8	308.4
1980	390.0	313.6	198.2	312.6
1981	377.0	306.0	183.0	315.8

The largest (coolest) summer index values are noted in 1973, 1976 and 1978. Definite trend reversal toward warming began after the 1978 period of peak cooling and persisted to 1981.

Discussion and Further Analysis

The computed index values are useful in determining the relative size of the cool air pool, but the application of these data lacks regional geographic definition throughout the hemisphere. A synoptic study of the 5640-meter contour may provide additional insight into geographic or regional displacement including preferred trough or ridge positioning. To accomplish this, the original 36 individual lengths used in computing the index values were used to reproduce a synoptic climatology of the 5640-meter isoheight line. Ten year mean positions for some typical examples are presented in Figures 4, 5, 6, and 7. Seasonal geographic placement of this isoheight line will eventually be compared to the geographic placement of the polar jet, which is frequently thought of as the driving force within the westerlies for cyclogenesis.

The January 24 depiction in Figure 4 depicts an almost complete expanded pattern. Zonal (west to east) flow is dominant with few small scale oscillations. Azonal (meridional) flow is most apparent along 130°-160° W off the California coast. Some broad troughing is noted along the central Gulf coast. Deep contiguous ridging and troughing is evident from the eastern Iberian Peninsula to the Libyan desert.

The April 26 depiction in Figure 5 displays cross latitudinal flow in the United States, the central Atlantic, and over the Asian land mass. Area balance about the vortex is not as evident as in mid winter. Some accelerated contraction is noticeable on the North American and Asian land masses. Flow is much less zonal with multiple trough/ridge positioning from the water off the California coast to the southeastern seaboard and over the Aral Sea. Broad troughing is noted off the Southeastern Seaboard of the United States, across northern Africa, and over the islands of Japan.

The July 26 depiction in Figure 6 is shortly after the contractual minimum. The contour plot is asymmetric with elongation over the Atlantic and northern Pacific and contraction over the land masses. Troughing is evident over the cooler waters of the North Atlantic and eastern Pacific. Flow is typically azonal with multiple minor waves.

The October 25th map in Figure 7 displays a more balanced area depiction. Flow is more zonal again. Cross latitudinal flow is noted over the Pacific northwestern section of the United States. Elsewhere, there is little troughing.

A week to week wave count was completed (Table 5). The number of waves is at a minimum during the expansionary winter period and slowly builds to a maximum dur-

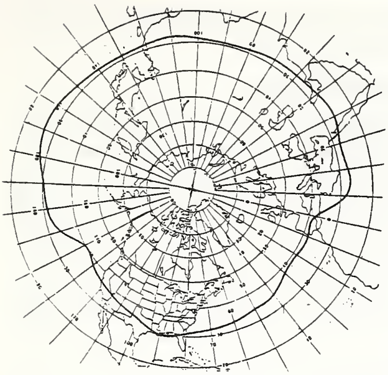


FIGURE 4. 5640-meter contour plot. 10 year mean. January 24 (week 4).

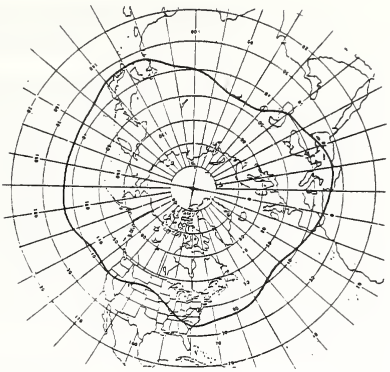


FIGURE 5. 5640-meter contour plot. 10 year mean. April 26 (week 17).

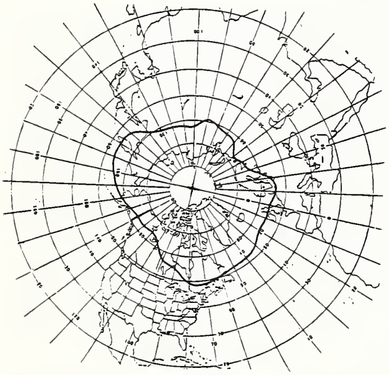


FIGURE 6. 5640-meter contour plot. 10 year mean. July 26 (week 30).

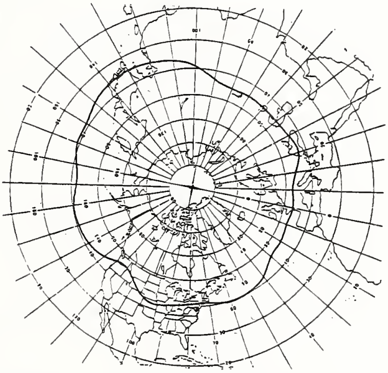


FIGURE 7. 5640-meter contour plot. 10 year mean. October 25 (week 43).

TABLE 5. Weeky Wave Count.

Week	Count	Week	Count	Week	Count	Week	Count
1	4	14	7	27	11	40	7
2	3	15	6	28	11	41	6
3	3	16	7	29	9	42	4
4	3	17	6	30	7	43	5
5	3	18	4	31	8	44	5
6	3	19	6	32	6	45	6
7	2	20	6	33	6	46	5
8	5	21	7	34	7	47	6
9	4	22	8	35	7	48	6
10	5	23	5	36	7	49	5
11	5	24	6	37	8	50	3
12	4	25	8	38	6	51	5
13	7	26	7	39	7	52	6

ing the traditional summer. This suggests that wave number can be used in developing additional information related to season temperature trends.

Conclusion and Recommendations

The area index developed appears to be representative of hemispheric seasonal trends in surface temperature. Seasonal timing differential and statistical manipulation of normalized index values can offer additional corroborative evidence about these trends. The synoptic study of the 5640-meter contour appears to be a promising source to identify preferred troughing and ridging positioning which may provide the regionalization necessary to link the hemispheric area index to surface temperature forecasts. Much remains to be done, and an actual hemispheric temperature data base is being sought to relate these seasonal circumpolar area index patterns to seasonal trends in surface temperature.

Acknowledgment

The authors would like to thank Dr. Robert Dale for his guidance and support.

Literature Cited

Angell, J.K. and J. Korshover. 1977A. Variation in size and location of the 300mb North Circumpolar Vortex between 1963 and 1975. Mon Wea Rev., 105:19-25.

Angell, J.K. and J. Korshover. 1977B. Estimate of the global change in temperature, surface to 100mb, between 1985 and 1975. Mon Wea Rev., 105:375-385.

Angell, J.K. and J. Korshover. 1978A. The expanded north circumpolar vortex of 1976 and winter of 1976-77, and attendant vortex displacement. Mon Wea Rev., 106:137-142.

Angell, J.K. and J. Korshover. 1978B. Global temperature variation, surface 100mb. An update into 1977. Mon Wea Rev., 106:755-770.

Angell, J.K. and J. Korshover. 1978C. Estimate of global temperature variations in the 100-30mb layer between 1958 and 1977. Mon Wea Rev., 106:1422-1432.

Peterlin, Albert. 1981: A Circumpolar Areal Indexing Technique for Predicting Seasonal Surface Temperature Trends. Master of Science Thesis, Life Science Library, Purdue University, W. Lafayette, In 47906. 55p.

The Effects of Bulk Density on Available Moisture in Selected Surface Mine Soil Materials

G.C. Steinhardt, W.C. Moldenhauer and D.P. Franzmeier
Department of Agronomy
Purdue University
West Lafayette, Indiana

Introduction

There is considerable interest in the effects of surface mining and subsequent reclamation on soil productivity. One concern is the amount of soil compaction that results from current surface mine reclamation techniques. Previous work has looked at methods to improve drainage or promote root growth. This article considers the potential effect of soil compaction on plant available water in the soil.

Literature Review

Numerous studies have been conducted in the Midwest to evaluate properties and productivity of soils following reclamation after surface mining (Henning, 1979; Fehrenbacher et al., 1982; Stein, 1983; McSweeney and Jansen, 1984). Some have examined alternative reclamation techniques and others have examined soil management. Crop yields on reclaimed soils have in general been variable with weather, which is also typical of unmined soils. The reclaimed soils, however, show considerably more variability in yields, obtaining near normal yields with good rainfall but more drastic yield reductions if water content is deficient. This is very similar to results obtained in intentionally compacted plots (Gaultney, et al., 1982).

Soil compaction can lead to moisture stress (Byrnes, et al., 1982) and excessive soil compaction in the reclaimed soil may be causing the moisture stress observed due to reductions in available water.

Methods

Bulk soil samples were taken from each of three surface mine sites in southeastern Indiana. The location of these mine sites, original soil, classification and particle size analysis are shown in Table 1. Samples were taken from the surface layer of the reclaimed soil, which is a mixture of A and B horizons from the original soil at the site. The classification of the soils originally present indicates that a fragipan was present in two of the three original soils. The fragipan material was not used in this study.

Table 1. Surface Mine Locations and Soil Characteristics.

				Particle-Size Analyses	
Mine	County	Original Soil	Classification	Silt %	Clay %
Ayrshire	Warrick	Hosmer silt loam	Typic Fragiudalf	70	21
Solar Sources	Pike	Alford silt loam	Typic Hapludalf	74	19
CHinook	Clay	Ava silt loam	Typic Fragiudalf	70	18

The bulk soil samples were all silt loam texture. Even though it was a mixture of two horizons the soil materials were fairly uniform. To insure consistent packing the air dry soils were crushed and passed through a 2 mm sieve. Water was slowly added to the soil and thoroughly mixed. The final water content was in the range of 15 to 20% on an oven dry basis. Water content samples were taken and the exact water content determined. The container was sealed and the wet soil was allowed to stand overnight to equilibrate.

Soil cores of different bulk densities were obtained by placing a known weight of soil, corrected for water content, in a brass ring of known volume. The soild was compressed in the brass ring using a specially designed mold. When the mold was squeezed between the plates of a hydraulic press, the piston compressed the soil until it was confined within the volume of the brass ring. This resulted in bulk density samples that were quite predictable and consistent. Three replicate samples at each tested bulk density were prepared and the results averaged. Ten density levels for soils from the Ayrshire mine, five for Chinook and 12 for Solar Sources were used.

Water Retention Measurement

The compacted bulk density samples were saturated from below in a pan starting with water at approximately 1 cm depth for 24 hours and then raising the water level to the top of the core for another 24 hours. The soil samples were weighed at saturation and after equilibration at 0.01 MPa, 0.03 MPa and 1.5 MPa tension. The soil water tensions were produced using pressure plates and standard techniques (Richards, 1965). After determining the weight at 1.5 MPa tension the samples were oven dried and the water content at saturation and at each tension was calculated as a percentage of the oven dry weight of the soil. This permitted easy calculation of water content between various tensions measured.

Results and Discussion

The particle-size distributions are very similar for all of the mine sites (Table 1). This was expected due to the similar eolian nature of the parent materials of the natural soils.

Figure 1 contains the water retention data for all samples for all three sites. After plotting the results of each site separately it was found that all three sites followed the same relationship. This would probably not be the case if the particle-size distributions were not similar. The results for the three replicate samples of each bulk density were very close.

There is a close relationship between the saturated water content and the bulk density. The r^2 for the regression (Figure 2) of saturated water content on bulk density was 0.87. As bulk density is changed pore volume is directly affected. A similar r^2 value, 0.78, was found for soil water at 0.01 MPa tension. The r^2 value for 0.03 MPa tension is lower. Soil water content at a tension of 1.5 MPa is not related to bulk density. Moisture contents at 0.03 and 1.5 MPa are probably related more to particle-size distribution (Franzmeier et al., 1960) but these data do not address that issue.

In previous studies (Richards, 1965), the water contents at both 0.01 MPa and 0.03 MPa have been used to estimate field capacity. There is considerable controversy about whether or not either of these is a valid approximation of field capacity (Hillel, 1980). However, Franzmeier, et al. (1960) demonstrated a fairly close relationship of soil water at 0.006 MPa tension and field measurements of field capacity for over 90 Midwest soils. For this study 0.01 MPa was used as the estimated field capacity, realizing that there may be some limitations. If the water content at 1.5 MPa is taken as the permanent wilting point, the percentage of available water in the soil can be calculated as the difference between water content at 1.5 MPa and that at 0.01 MPa. This can be done from the data in Figure 2 for any bulk density from 1.3 Mg/m^3 to 1.9 Mg/m^3. This allows

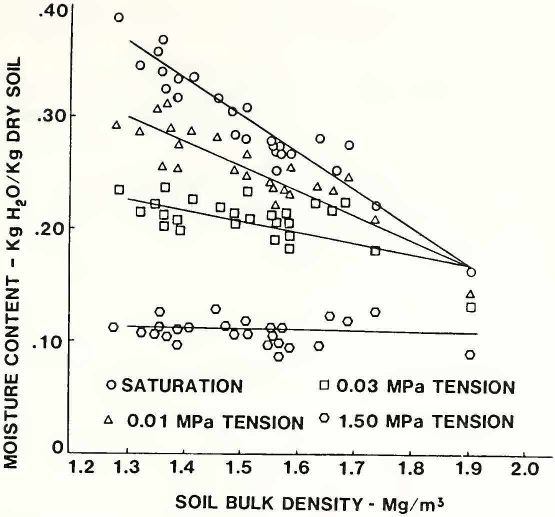


Figure 1. Moisture content at various soil moisture tensions.

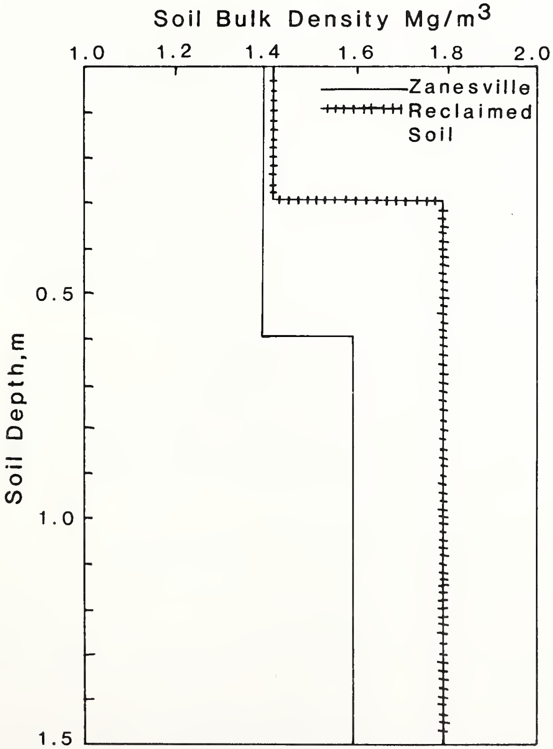


Figure 2. Bulk density of Zanesville silt loam and a reclaimed soil at Solar Sources Mine.

calculation of the available water that would be expected in a natural soil for comparison to what might be found with a reclaimed soil.

Approximate soil bulk density profiles for a Zanesville silt loam and the reclaimed soil at the Solar Source mine are shown in Figure 2 to a depth of 1.5 m. The Zanesville soil densities are from Wiersma (1984) and the reclaimed soil densities are from Stein (1983).

At a bulk density of 1.4 Mg/m^3 the water content is 0.28 Mg H_20/Mg soil at 0.01 MPa and 0.11 Mg H_20/Mg soil at 1.50 MPa for a difference (available water) of 0.17 Mg H_20/Mg soil. Assuming the density of water is 1.00 Mg/m^3 then:

$$\frac{1.40 \text{ Mg soil}}{\text{m}^3 \text{ soil}} \times \frac{0.17 \text{ Mg H}_20}{\text{Mg soil}} \times \frac{1.00 \text{ m}^3 \text{ H}_20}{1.00 \text{ Mg H}_20} = \frac{0.24 \text{ m H}_20}{\text{m soil}}$$

Similarly, the available water content is 0.20 m/m at a bulk density of 1.6 Mg/m^3 and 0.15 m/m at a bulk density of 1.8 Mg/m^3. Then assuming the bulk density profiles in Figure 2, the available water in 1.5 m of the Zanesville soil is

$$\frac{0.24 \text{ m H}_20}{\text{m soil}} \times 0.60 \text{ m soil} + \frac{0.20 \text{ m H}_20}{\text{m soil}} \times 0.90 \text{ m soil} = 0.32 \text{ m H}_20$$

and in 1.5 m of reclaimed soil it is

$$\frac{0.24 \text{ m H}_20}{\text{m soil}} \times 0.30 \text{ m soil} + \frac{0.15 \text{ m H}_20}{\text{m soil}} \times 1.20 \text{ m soil} = 0.25 \text{ m H}_20$$

The results are shown in Table 2.

TABLE 2. Comparison of Zanesville Silt Loam and Reclaimed Soil at Solar Sources Mine.

	Plant Available Moisture Stored 1.5 m	Moisture Required For Corn	Rainfall Required June-Aug	Approximate Probability of Adequate Rain
	mm	mm	mm	%
Zanesville Silt Loam	320	500	180	83
Reclaimed Soil	250	500	250	48

A corn crop requires approximately 500 mm of water to reach full yield potential Rainfall during the growing season must supplement the amount stored initially in the soil. Figure 3 shows the probabilities of a given amount or more of rainfall during the June through August period. These estimates are calculated from the gamma distribution parameters for two- and three-week precipitation totals based on 54 years (1901-1954) at Mt. Vernon, Indiana (Barger et al., 1959, p. 26). The Zanesville soil requires 180 mm of rainfall to obtain adequate water for a corn crop (Table 2). There is an approximate 83% chance this will happen. On the other hand there is only a 48% chance that the reclaimed soil will receive the necessary 250 mm of rainfall. These probabilities do not address the question of distribution or timeliness of the rainfall.

Although there may be room for interpretation as to the upper limit of available water or a specific density profile, the probability figures in Table 2 do point out one of the serious limitations of reclaimed soils. The compacted soils are so dense that they do not store enough water to supply crop needs in most years. Unfortunately deep tillage may not be a solution to this aspect of the compaction problem. Deep tillage may improve permeability and rooting but the dense clods may still not be capable of storing adequate moisture.

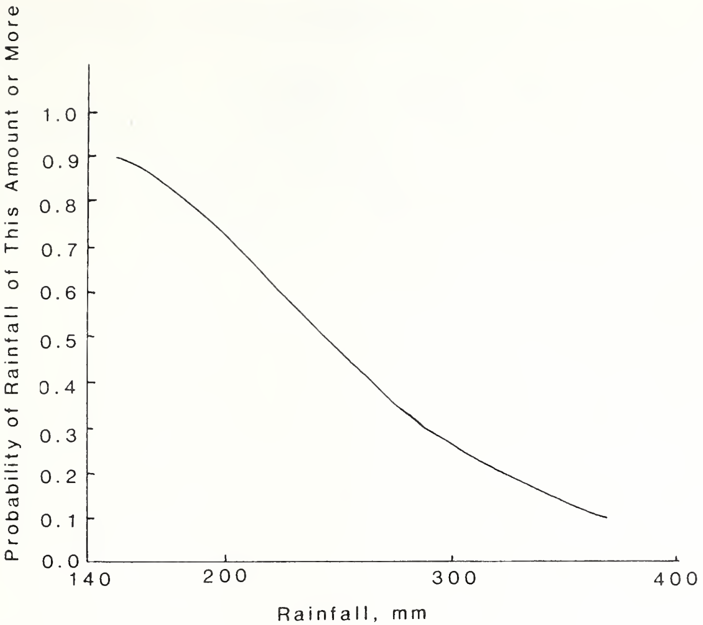


FIGURE 3. Rainfall probability, June thru August, Mt. Vernon, IN.

The ultimate solution may be selection of an alternative approach to reclamation that reduces reliance on scrapers and bulldozers working with relatively thin layers of soils.

Acknowledgments

Support for this work was provided by Research Grant No. G5115181 from the Office of Surface Mining, U.S. Department of the Interior. Journal Paper No. 10,996. Purdue Agric. Exp. Sta.

Literature Cited

Barger, G.L., R.H. Shaw and R.F. Dale. 1959. Gamma distribution parameters from 2 and 3 week precipitation totals in the north central region of the United States. Project 1280. Iowa Agricultural Experiment Station, Ames, IA. 183 pp.

Byrnes, W.R., W.W. McFee and G.C. Steinhardt. 1982. Soil compaction related to agricultural and construction operations. Sta. Bull. 397. Agr. Exp. Sta. Purdue Univ. 164 pp.

Fehrenbacher, D.J., I.J. Jansen and J.B. Fehrenbacher. 1982. Corn root development in constructed soils on surface-mined land in western Illinois. Soil Sci. Soc. Am. J. 46:353-359.

Franzmeier, D.P., E.P. Whiteside and A.E. Erickson. 1960. Relationship of texture classes of fine earth to readily available water. 7th Intl. Cong. of Soil Sci. Vol. 1 pp. 354-363.

Gaultney, L., G.W. Krutz, G.C. Steinhardt and J.B. Liljedahl. 1982. The effects of subsoil compaction on corn yield in Indiana. Trans. ASAE 25:3;563-569.

Henning, S.J. 1979. Experiences in farming reclaimed mined land — small operations and small sites. p. 70-79. In Proceedings Prime Farmland Reclamation Workshop, Ind. Univ.-Purdue Univ. Indianapolis, Indianapolis, IN.

Hillel, D. 1980. Applications of soil physics. Academic Press. New York, NY.

McSweeney, K. and I.J. Jansen. 1984. Soil structure and associated rooting behavior in mine soils. Soil Sci. Soc. Am. J. 48:607-612.

Richards, L.A. 1965. Physical conditions of water in soil. p. 128-152. In C.A. Black (ed) Methods of soil analysis Part 1. Am. Soc. Agron. Monograph 9. Madison, WI.

Stein, O.R. Jr., 1983. Erodibility and related soil properties of three reclaimed surface mined soils. M.S. Thesis. Purdue University, West Lafayette, IN.

Wiersma, D. 1984. Soil water characteristic data for some Indiana soil profiles. Stn. Bull. 452. Purdue Univ. Agr. Exp. Stn. W. Lafayette, IN 153 pp.

ZOOLOGY

Chair: Ronald L. Richards
Indiana State Museum
202 N. Alabama Street
Indianapolis, Indiana 46204 (317) 232-1637

Chair-Elect: Albert A. Williams
Department of Biology
Manchester College
N. Manchester, Indiana 46962 (219) 982-2141 ext. 308

ABSTRACTS

A Pigmented Northern Blindfish, *Amblyopsis spelaea*, and Notes on Pigmentation in Amblyopsid Cavefishes. Claude D. Baker, Indiana University Southeast, New Albany, Indiana 47150.——An unusual adult specimen of northern blindfish, *Amblyopsis spelaea*, exhibited a striking bicolor pigmentation pattern. Previous investigators have considered pigment loss irreversible and subsequent pigment reappearance unlikely. During normal development of this species, pigment disappears under natural light or laboratory illumination. The gross anatomical and histological characteristics of the pigmentation pattern were studied. Additional work was undertaken to update information on pigmentation in the amblyopsid cavefishes.

Proteolytic Enzymes in Brook Trout and Goldfish Follicles during Final Maturation and Ovulation. Amy K. Berndtson and Frederick W. Goetz. University of Notre Dame, Notre Dame, Indiana 46556.——Follicular proteolytic activity was observed, using substrate-gel electrophoresis, in brook trout (*Salvelinus fontinalis*) and goldfish (*Carassius auratus*) oocytes at different stages throughout final maturation and ovulation. Follicular extracts were resolved on a 12.5% polyacrylamide gel containing 0.1% gelatin as the substrate. Proteolytic enzymes were observed as clear zones of digestion against the blue protein background after the gel was incubated in a reaction buffer and stained with 0.1% Amido Black. Five major enzymes were observed in both brook trout and goldfish follicles. In both species, the activity of two enzymes (28,000 and 80,000 mol wt) decreased before final maturation and the activity of two other enzymes (25,000 and 67,000 mol wt) increased before ovulation. Investigations on goldfish follicles using proteolytic enzyme inhibitors suggest that the 25,000 and 28,000 mol wt enzymes are serine proteases, the 80,000 mol wt enzyme is a Ca-dependent serine protease and the 67,000 mol wt enzyme is a metallo-protease. Supported by a research grant from the Indiana Academy of Science.

A Study of Adenosine Deaminase in the Fruit Fly, *Drosophila melanogaster*. David L. Brand and Pang F. Ma, Center for Medical Education, Ball State University, Muncie, Indiana 47306.——Adenosine deaminase catalyzes the deamination of adenosine to inosine in the purine degradation pathway. Three forms of this enzyme are known to exist in animal tissues, each with its own characteristic molecular weight. Masses of 200,000 (form A), 100,000 (form B) and 35,000 (form C) have been estimated by gel filtration column chromatography. These enzyme forms are present in various proportions in different organisms and exhibit tissue specificity. The B form is not found in advanced mammals. The enzyme activity level and form distribution patterns are known to change during the process of development of certain organisms. Very little is known about this enzyme in insects. In this study, adenosine deaminase is isolated from the fruit fly of the genus *Drosophila melanogaster*. The activity level will be measured at various stages of development of the fruit fly. The molecular weight and some kinetic parameters also will be determined.

Studies of Ecology, Ectoparasites, and Other Associates of the Eastern Box Turtle, *Terrapene carolina*. PRISCILLA COSTELLO, Terre Haute South High School, Terre Haute, Indiana 47802.——The purpose of this study was two-fold. The first objective was to analyze four years of data of 20 Eastern box turtles, *Terrapene carolina* confined in a 22 ′ x 19 ′ study area. The data include measurements, records on behavior and hibernation, and maps of home ranges. The second objective was to study the ectoparasites and associates of the confined turtles and to compare these data with those of turtles taken directly from the field. Five basic types of associates were found. They are currently being identified, but apparently none are truly parasitic.

Histopathology of Experimental *Dendritobilharzia pulverulenta* Infections in Avian Hosts. DAVID L. DANIELL, Butler University, Indianapolis, Indiana 46208.——Eggs deposited by *Dendritobilharzia pulverulenta* females in the arterial system of experimentally infected avian hosts frequently are carried to tissues other than the intestinal wall, and thus can not escape from the host. Schistosome eggs were found in kidney, lung, liver, pancreas and brain tissues of laboratory-infected mallards, muscovy ducks, Canada geese, and domestic chickens. Stained sections of these organs reveal lesions containing eggs accompanied by varying degrees of inflamatory reaction and granuloma formation. A typical large granuloma contains numerous multinucleated giant cells, a layer of fibroblasts and fibers, and an irregular outer layer of leucocytes (mainly lymphocytes and granulocytes).

Improved Analysis of Physical Forces and Tissue Rheology in Amphibian Gastrulation. GRAYSON S. DAVIS, Valparaiso University, Valparaiso, Indiana 46383.——Cellular aggregates of deep ectoderm, deep mesoderm, and deep endoderm excised from *Rana pipiens* gastrulae undergo movements in organ culture which often mimic normal gastrulation. Such movements resemble the flow of viscous liquids, suggesting that surface tension, which directs ordinary liquid flow, also may direct similar movements of certain living tissues. Indeed, these tissues demonstrably possess the physically-defined (*i.e.*, area-invariant) surface tensions appropriate to entirely account for their liquid-like *in vitro* rearrangements. Unfortunately, quantification of a living tissue's surface tension requires many measurements including a tedious and somewhat subjective curve-matching step, which makes the result prone to random error. A new method using a microcomputer and digitizing tablet makes this analysis much faster, easier and more reliable. This method: 1) provides the correct value for air-water interfacial surface tension and 2) preliminarily indicates that aggregates of deep ectoderm enveloped with surface ectoderm (coat) are not liquid-like, but instead have area-dependent surface tensions just as do elastic solids.

Localization of Acetylcholine Binding Sites in Prepubertal Mouse Ovaries. LARRY R. GANION AND MARY E. MOHR, Ball State University, Muncie, Indiana 47306.——It has been demonstrated that oocytes of several animal species respond to acetylcholine, which suggests the presence of acetylcholine receptors in the oocyte membrane. To assess the site of acetylcholine binding, ovarian fragments from prepubertal, HS mice were cultured at 37 °C *in vitro* in Eagle's medium containing H^3 - acetylcholine (68 μc/ml) for 60 minutes. Next the tissues were rinsed, fixed in 3% glutaraldehyde, and embedded in paraffin. Sections were cut, coated with Kodak NTB-2 emulsion, exposed for 20 days, developed, and stained. As revealed from the autoradiographs, the label is primarily associated with the secondary ovarian follicles. In such follicles, most of the silver grains are concentrated over the follicular envelope and localized between and on the surface of follicle cells. In some follicles, the oolemma is extensively labelled. These data suggest that acetylcholine receptors are present in ovarian follicles. Additional studies are planned to check binding specificity. The possible function of acetylcholine in the biology of the ovarian follicle will be discussed.

Sterilization of Chinook Salmon, *O. tshawytascha*, Fry by 17α-methyltestosterone. FREDERICK W. GOETZ, F.P. BINKOWSKI, P.D. LORSCH AND S.E. YEO. University of Notre Dame, Notre Dame, Indiana 46556 and University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53204.——Chinook salmon were treated with 17α-methyltestosterone (17-MT) by periodic immersion (400-800 ug/1 wellwater) during the alevin stage. Low frequency (2 immersions) and high frequency (5-10 immersions) treatments were conducted. 17-MT treatment was continued in the diet at 4 levels: 10, 20, 40 and 80 mg/kg diet for 8-16 weeks depending on treatment. Fry were sampled at swim-up, and 4, 8, 12 and 16 weeks of feeding and the gonads assayed histologically. Phenotypic sex (i.e. testes and ovaries) differentiation could be distinguished by 4 weeks in control fry though an accurate sex ratio was not always possible at this time. All fry that received 17-MT by immersion and in the diet, exhibited some sterilization of the gonads. Many gonads had greatly reduced numbers of germ cells and stromal tissue and an increase in connective tissue. There was an increase in the amount of sterilization observed with 1) higher 17-MT immersion frequencies, 2) higher dietary 17-MT concentrations and 3) longer dietary treatments. The results indicate that sterilization of chinook salmon is possible with certain 17-MT treatment regimens. Project funded by the Wisconsin Department of Natural Resources.

Habitat and Food Interrelationships of Shrews in West Central Vigo County. RONALD L. HELMS, West Vigo High School, West Terre Haute, Indiana 47885.——Shrews were trapped using sunken pit traps at both moist and dry locations in a variety of habitats varying from old field to woods.

Differences in food utilization by *Blarina brevicauda* and *Sorex* sp. and shifts in food utilization with differing habitats are being analyzed. Stomach contents of specimens also are being analyzed to determine amounts and kinds of foods eaten. Diets of same or similar species studied elsewhere will be compared with the specimens collected in this study.

Ultrastructural Changes in the Proximal Tubule of the Axolotl. MOHINDER S. JARIAL, Center for Medical Education, Ball State University, Muncie, Indiana 47306 AND MARGARET W. EGAR, Department of Anatomy, Indiana University School of Medicine, Indianapolis, Indiana 46223.——Short finger mutants of *Ambystoma mexicanum* from the Bloomington colony were examined for ultrastructural changes in the mesonephros. Two of these adult animals expressed ascites as well as characteristic reduced limb and digit length. Upon gross dissection, one showed extreme kidney pathology. The short finger mutation was described by Humphrey (1967) as a recessive lethal trait that results in reduced digit and limb length, absence of the Mullerian duct, and with edema and/or ascites.

The grossly abnormal kidney had pathological changes at the ultrastructural level in the proximal tubule. These tubule cells were massively distended by multiple lysosomes, filled with small membrane bound bodies. Normal mitochondria were not found except in the distal tubule and collecting duct where the other cytoplasmic organelles are like those in the control kidney. The abnormal proximal tubule cells appear to have been involved in an autophagic reaction that left no functional cytoplasm at all.

Winter Fishes in Bayou Creek Drainage. SCOTT A. LEATHERLAND AND THOMAS H. CERVONE, University of Southern Indiana, Evansville, Indiana 47712.——In the winter of 1986, twenty-five species of fish from ten families were collected in Bayou Creek drainage. The most abundant fishes found were the emerald shiner, bluntnose minnow, bluegill, mosquitofish, and creek chub respectively. These five species comprised 80.5% of the entire collection, while disproportionately, the remaining twenty species made up but 19.5%. This exaggerated abundance of but a few fishes compounded with an average species diversity index of 1.5 ± 0.7 indicated a depressed fish fauna in Bayou Creek and its tributaries. The spottail darter, a special concern species in Indiana, was found in six of the twenty-six (23.1%) stations sampled. All collections of this darter were in headwater tributaries. Both the spottail and mud darters found in this investigation were new records for Vanderburgh County.

Coteratogenesis of Caffeine and Acetazolamide in Mice. CHARISSA M. URBANO AND SIDNEY L. BECK, Ball State University, Muncie, Indiana 47306.——Preliminary results suggest the positive coteratogenic effect of caffeine coadministered with acetazolamide to pregnant C57B1/JBk mice on day 9 of gestation. Subcutaneous injections of caffeine with a total dose of 50 mg/kg were followed immediately by injection of acetazolamide at total dosages of 200 mg/kg (low dose) or 1.00 g/kg (high dose) in three equal injections 7 hours apart. Females were sacrificed on day 18 by CO_2 asphyxiation and fetuses were removed and examined for gross malformations. A pronounced increase in fetal malformations, especially forelimb ectrodactyly, was evident in both low dose and high dose groups when contrasted with controls (untreated, vehicle-treated, caffeine, low dose or high dose acetazolamide). Other malformations observed included: hemimelia, anopthalmia, and agnathia.

Winter Fishes of Stinking Fork

David M. Agee, William J. Alvey, Kenneth D. Berger,
Brad J. Leinenbach and Thomas H. Cervone
University of Southern Indiana
Evansville, Indiana 47712

Introduction

Stinking Fork of the Little Blue River is located in unglaciated terrain of the Crawford Upland Region (14) in the southcentral counties of Crawford and Perry, Indiana. The stream flows for approximately 19 kilometers in a southeasterly direction to its confluence with the Little Blue River, a tributary of the Ohio River. Stinking Fork drains an area of 70.7 square kilometers (6) and elevations within the drainage basin are 137 to 232 meters above sea level. Small towns along its course are West Fork and Sulfur Springs (Figure 1).

Stinking Fork is located in the Hoosier National Forest. It is a moderate to fast-flowing upper perennial riverine ecosystem (2) comprised of many riffles and pools. It flows primarily through hydrophytic to mesophytic forests consisting of sycamore, oak, silver maple, beech and, to a much lesser extent, through agricultural and grazing lands.

To our knowledge, no previous work on fishes in Stinking Fork has been published. The only fish study near, but not in Stinking Fork, was in the Little Blue River and Big Blue River (3). The purpose of this study was to accumulate winter base-line data on the type, distribution, relative abundance, and species diversity of fishes in Stinking Fork and its tributaries.

Material and Methods

Twenty-one sites were sampled in Stinking Fork drainage (Figure 1). These were

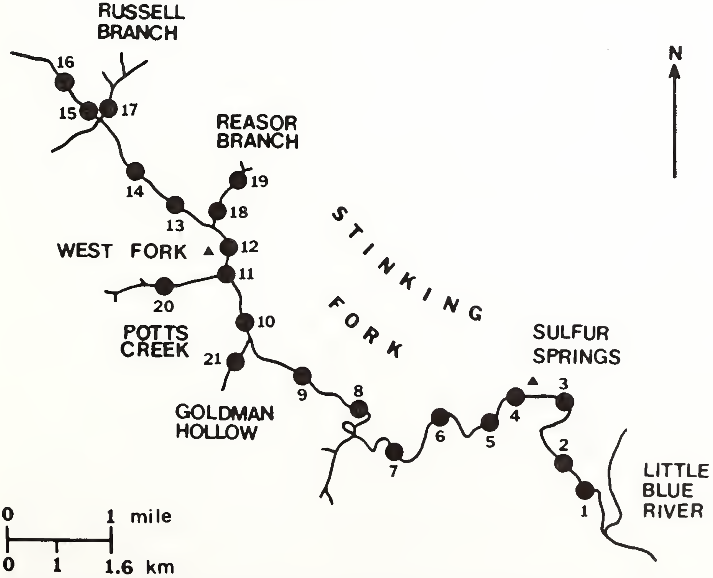


Figure 1. Map of Stinking Fork drainage. Solid circles represent collecting sites, while triangles depict towns.

Table 1. Frequency, Location and Diversity of Fish Species in Stinking Fork per Station

	STINKING FORK															SMALL TRIBUTARIES						
STATIONS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total
SPECIES																						
Campostoma anomalum (Central Stoneroller)	1			2			5	1	8	7	21	26	3	41	8	49	13	31	17	34	130	397
Ericymba buccata (Silverjaw Minnow)									7	1	13		17		10	22		1	3	1	5	80
Notropis ardens (Rosefin Shiner)	1		25	56	2	50	108		16	9	24	25	36	4	54	38		1		2	59	510
Notropis atherinoides (Emerald Shiner)	7																					7
Notropis chrysocephalus (Striped Shiner)			12	172	20	54	396	1	52	9	56	14	37	17	24	88	39	34	49	2	131	1207
Phoxinus erythrogaster (Redbelly Dace)													1	55		44	53	27	50	5	17	252
Pimephales notatus (Bluntnose Minnow)			1	28	5	274	19		101	54	128	11	15	58		82	1	4	8	3	115	907
Semotilus atromaculatus (Creek Chub)									4			1	3	29		48	23	11	42	1	11	173
Catostomus commersoni (White Sucker)																4						4
Hypentelium nigricans (Hog Sucker)	1		2	2	2	1	1	1	3	1	1	1	1									17
Moxostoma duquesnei (Black Redhorse)											1			3								4
Moxostoma erythrurum (Golden Redhorse)	1		1	1		1			1												2	7
Labidesthes sicculus (Brook Silverside)						3																3
Ambloplites rupestris (Rock Bass)			1												1							2
Lepomis humilis (Orangespotted Sunfish)							1															1
Lepomis megalotis (Longear Sunfish)				3		1																4
Etheostoma blennioides (Greenside Darter)			7																			7
Etheostoma caeruleum (Rainbow Darter)	4	6	1	7	8	6	7	2	17		4	3		2	1	1				1	1	71
Etheostoma flabellare (Fantail Darter)	22	22	6	8	23	13	6	11	31	22	18	13	3	6	11	1	10	2	2	8	1	239
Etheostoma nigrum (Johnny Darter)		1	4	2	3	14	3		3	1												31
Etheostoma spectabile (Orangethroat Darter)	1				2	1			2	22	3	2		1	2	1		2	11	5	6	61
Cottus carolinae (Banded Sculpin)		2		2	3	1		1							1		2		1			13
Total Number of Species	8	4	10	11	9	12	9	6	12	9	10	9	9	10	9	11	7	9	9	10	11	22
Total Number of Individuals	38	31	60	283	68	419	546	17	245	126	269	96	116	216	112	378	141	113	183	62	478	3997
Species Diversity (H′)	1.9	1.2	2.5	1.8	2.5	1.7	1.3	1.7	2.6	2.3	2.3	2.6	2.4	2.6	2.2	2.8	2.2	2.4	2.5	2.3	2.4	

TABLE 1.—Continued

SPECIES	% OF TOTAL CATCH	% FREQUENCY OF OCCURRENCE
Campostoma anomalum (Central Stoneroller)	9.9	81.0
Ericymba buccata (Silverjaw Minnow)	2.0	47.6
Notropis ardens (Rosefin Shiner)	12.8	81.0
Notropis atherinoides (Emerald Shiner)	0.2	4.8
Notropis chrysocephalus (Striped Shiner)	30.2	90.5
Phoxinus erythrogaster (Redbelly Dace)	6.3	38.1
Pimephales notatus (Bluntnose Minnow)	22.7	81.0
Semotilus atromaculatus (Creek Chub)	4.3	47.6
Catostomus commersoni (White Sucker)	0.1	4.8
Hypentelium nigricans (Hog Sucker)	0.4	57.1
Moxostoma duquesnei (Black Redhorse)	0.1	9.5
Moxostoma erythrurum (Golden Redhorse)	0.2	28.6
Labidesthes sicculus (Brook Silverside)	0.1	4.8
Ambloplites rupestris (Rock Bass)	0.1	9.5
Lepomis humilis (Orangespotted Sunfish)	<0.1	4.8
Lepomis megalotis (Longear Sunfish)	0.1	9.5
Etheostoma blennioides (Greenside Darter)	0.2	4.8
Etheostoma caeruleum (Rainbow Darter)	1.8	76.2
Etheostoma flabellare (Fantail Darter)	6.0	100.0
Etheostoma nigrum (Johnny Darter)	0.8	38.1
Etheostoma spectabile (Orangethroat Darter)	1.5	66.7
Cottus carolinae (Banded Sculpin)	0.3	38.1

collected from 25 January to 22 February 1986. Each location was sampled using a combination of or singly a 4.3 × 1.1 meter (0.5 cm square mesh), 1.7 × 1.1 meter (0.6 cm ace mesh), or 1.7 × 1.3 meter (0.3 cm ace mesh) seine(s) for 0.5 to 1 hour. After collection, fish specimens were preserved in the field in 10% formalin. Fish specimens are presently housed within the University of Southern Indiana collection.

Species diversity: $H' = C/N\ (N \log_{10} N - \Sigma\ n_i \log_{10} n_i)$, where C is the constant for conversions of logarithms from base 10 to base 2 ($C = 3.32$); N equals the total number of individuals in the population; and n_i is the number of individuals of a particular species (4). Results are independent of sample size (10).

Fishes were identified to species using standard references (1, 8, 9, 12, 13). All scientific and common names in this report are currently acceptable names (11).

Results

Twenty-two species of fish from six families were collected in the Stinking Fork drainage. These species are listed with their distribution and relative abundance in Table 1. The fantail darter was ubiquitous, while the rosefin shiner, striped shiner, central stoneroller, bluntnose minnow, and rainbow darter were found in 75% or greater of the 21 stations sampled. The other sixteen species were restricted in their distribution in the drainage. The redbelly dace was found in the upper region of Stinking Fork and its small tributaries, while the hog sucker, golden redhorse, and johnny darter were limited to the middle and lower regions of the main stream. The few centrarchids found were restricted to the Sulfur Springs area and the emerald shiner was exclusively collected at Station 1 near the mouth. The creek chub, silverjaw minnow, and orangethroat darter were limited to the upper half of Stinking Fork drainage, while the banded sculpin demonstrated a uniquely disjunct distribution. It was collected in the headwater tributaries above West Fork, absent in Stinking Fork above and below West Fork, and found again in the middle and lower regions of the main stream. The black redhorse was found at two headwater stations, whereas the white sucker, greenside darter, and brook silverside were collected at only one station in this study. The white sucker was found in the upper headrun of Stinking Fork (Station 16); the brook silverside in the middle region of the main stream (Station 6); and the greenside darter in the lower region (Station 3). The distributions of the orangethroat and rainbow darters were different. The orangethroat darter outnumbered the rainbow darter in the headwaters, while the rainbow darter outnumbered the orangethroat darter in the lower region of Stinking Fork (2 × 3 Chi Square = 29.2; df = 2; $p < .005$). Their numbers were similar in the middle region.

The most abundant fishes in Stinking Fork drainage were the striped shiner and bluntnose minnow (Table 1). These 2 species comprised 52.9% of the total catch. The rosefin shiner, central stoneroller, redbelly dace, creek chub, and fantail darter made up 39.3% of the total catch. Together, the above 7 species comprised 92.2% of the collection, while the remaining 15 species constituted but 7.8% of the total catch. Ninety-eight percent of the fishes collected in Stinking Fork drainage belonged to the minnow (88.4%) and darter (9.6%) families.

The species diversity of fishes in Stinking Fork drainage (Table 1) ranged from 1.2 to 2.8 and averaged 2.2 ± 0.4. Species diversity was rather uniform and averaged 2.4 ± 0.2 (N = 13; Range = 2.2 to 2.8) upstream from Station 9 and 1.8 ± 0.5 (N = 8; Range = 1.2 to 2.5) downstream. The lowest diversity indexes found were at Stations 2 and 7.

Discussion

Eighty-eight percent of the fishes collected in this study belonged to the minnow family. The most abundant minnows were the striped shiner, bluntnose minnow, rosefin shiner, central stoneroller, redbelly dace, and creek chub, all common inhabitants of pools in small streams. Their abundance is reflective of the number and extent of pools available in Stinking Fork drainage. The silverjaw minnow was collected in modest numbers and limited to the upper half (Station 9 on upstream) of Stinking Fork drainage. The silverjaw minnow is a sand-inhabiting species and reaches its greatest abundance only in brooks and small streams of moderate gradients where the sand on the bottom of the pools, bars, and riffles are free from a covering of clayey silts (13). We found from Station 8 to the mouth of Stinking Fork an increase in silty mud. Such conditions presumably exclude the silverjaw minnow from this region of the drainage. The rosefin shiner is allopatric with the redfin shiner in southern Indiana (3). We found only the rosefin shiner in this investigation. This species inhabits smaller and swifter streams than the redfin shiner (13).

Of the twenty-two species of fish collected in this investigation, the redbelly dace was the only species not collected previously in Crawford or Perry counties (3). In Gerking's monumental, statewide survey of 720 sites sampled in the summers of 1940 to 1943, he never collected the redbelly dace any further south than the White River drainage. Our recent discovery of this new Crawford County record in Stinking Fork probably represents an isolated population that existed during his time, but not sampled since he never ventured into Stinking Fork and because this fish tends to occur as isolated populations at widely spaced intervals (9). Its preferred habitat is spring-fed brooks and other clear, cool streams in wooded ravines (12) with overhanging vegetation (5). Streams of clear, cool water with "cut banks" are prime habitat (13). It is a gregarious fish often found in association with the central stoneroller and creek chub (9).

The most abundant species of sucker collected in Stinking Fork was the hog sucker. From our experience, the hog sucker is usually accompanied by the white sucker. However, we found a disporportionate ratio of 17 hog suckers to 4 white suckers with the former species collected at 12 stations; whereas, the latter species at only one station. The hog sucker prefers riffles, while the white sucker inhabits pools (3). Both suckers are migratory and winter in larger streams (13). With commencement of water temperatures of 4° C or greater, Trautman found in Ohio a vernal migration of these two species into tributaries for spawning purposes. In this study, the hog sucker probably was first to migrate upstream and this is why they were collected more than the white sucker, especially since all of the white suckers collected were of pre-reproductive age. Other suckers found in Stinking Fork were the black and golden redhorses. Their numbers were similar, but the black redhorse was found in the headwaters, while the golden redhorse was collected in the middle to lower regions of the drainage. Where these two species occur together, the black redhorse tends to predominate in short, rocky pools with current, whereas, the golden redhorse is most abundant in larger pools and backwaters without noticeable current (9).

The banded sculpin demonstrated a disjunct and puzzling ditribution in Stinking Fork drainage. Its hiatus was above and below the town of West Fork, Indiana. We attribute this distribution to an impermanence in flow, substrate, or possibly to pollution since sculpins are sedentary fishes. In contrast, the more mobile sunfishes in Stinking Fork were unexpectedly low in number and restricted in their distribution. Their scarcity in the drainage may be attributed to the season for they, like the suckers, probably winter in deeper waters of the Little Blue River. A summer investigation of Stinking Fork drainage would be interesting to substantiate or refute such speculation.

The rainbow darter outnumbered the orangethroat darter in the deeper, lower region of the drainage, while the opposite was true in the shallower headwaters. Interspecific competition is suggested for these two species (13). Stream size, depth and speed of current determines for the most part which species will become established and which species will be supplanted. The orangethroat darter prefers small to moderate, first-order and limestone-bedded second order streams with riffles of relatively low gradient and with a depth often 6 inches or less (1, 7). In contrast, the rainbow darter prefers moderate to large, third-order streams with wide riffles of at least moderate to high gradient and minimum of 6 to 12 inches (1, 7, 13). In the middle region of Stinking Fork, the above environmental preferences of each species overlapped and coexistence appeared operative. Furthermore, the greenside darter usually occurs in the same habitat as the rainbow darter (1). Our results concur even though the greenside darter was found only at one station near the mouth. The fantail darter was cosmopolitan in Stinking Fork drainage. Their abundance usually indicates the presence of a variety of fishes (7) as demonstrated in this investigation. Finally, the johnny darter was limited to the middle and lower regions of Stinking Fork. It is tolerant of a number of diverse conditions (13), but prefers shallow, slow-flowing pools (1). This habitat is especially available in the middle and lower regions of Stinking Fork. Darters comprised 9.6% of the total catch in this study. Their abundance is reflective of the number and extent of riffles available in the drainage.

The species diversity observed in Stinking Fork drainage was good for a stream of its size. Indexes from Station 9 on upstream were relatively stable; however, species diversity downstream of Staion 9 fell dramatically. Diversity should have increased with flow creating more habitats and thus, more species in the lower region of the drainage. However, this was not the case. It was found that the lower stations in the drainage displayed mud to organic sediments and seining was difficult. Whether anoxic sediments or bias in sampling or both produced such results is unknown. A preferred method of collection in this region of the drainage may be electroshocking the pools along with seining the riffles.

Conclusion

Stinking Fork drainage is a fast to moderate-flowing riffle and pool ecosystem and consequently, demonstrated in our winter study a predominance of minnows and darters. Twenty-two species of fish from six families were collected in this investigation. The redbelly dace, a new record for Crawford County, was discovered in the upper headwaters. The most abundant species were the striped shiner and bluntnose minnow. Interspecific competition between the rainbow darter and orangethroat darter appeared operative in the drainage as demonstrated by their distributions. The distribution of the banded sculpin was puzzling. The species diversity was good for a small stream and averaged 2.2 ± 0.4. A depressed fish fauna was evident in the lower region of Stinking Fork.

Acknowledgments

We would like to thank the following people for their contributions to our project: James Bandoli, Marie Cervone, Edward Clutinger, Melvin Denner, Anna Glaser, members of the Aquatic Biology Class (University of Southern Indiana), and the Foundation of the University of Southern Indiana. A special thanks is extended to James Gammon of DePauw University (Greencastle, Indiana) for his suggestions to study this drainage.

Literature Cited

1. Clay, W.M. 1975. The Fishes of Kentucky. Kentucky Dept. of Fish and Wildlife Resources, Frankfort, Kentucky. 416 pp.
2. Cowardin, L.M., V. Carter, F.C. Golet, and E.T. Laroe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. Fish and Wildlife Services, U.S. Dept. of the Interior. 104 pp.
3. Gerking, S.D. 1945. The Distribution of the Fishes of Indiana. Investigations of Indiana Lakes and Streams, 3(1):1-137.
4. Hair, J.D. 1980. Measurement of Ecological Diversity (Chap. 16) in Wildlife Management Techniques Manual (4th ed., revised). Edited by Sanford D. Schemnitz. The Wildlife Society, Inc. pp. 269-275.
5. Harlan, J.R. and E.B. Speaker. 1969. Iowa Fish and Fishing (4th ed.). Iowa Conservation Commission. 77 pp.
6. Hoggatt, R.E. 1975. Drainage Areas of Indiana Streams. U.S. Dept. of the Interior, Geological Survey, Water Resources Division. 231 pp.
7. Kuehne, R.A., and R.W. Barbour. 1983. The American Darters. The University Press of Kentucky, Lexington, Kentucky. 177 pp.
8. Nelson, J.S. and S.D. Gerking. 1968. Annotated Key to the Fishes of Indiana. Dept. of Zoology, Indiana University, Bloomington, IN. 84 pp.
9. Pflieger, W.L. 1975. The Fishes of Missouri. Missouri Dept. of Conservation. 343 pp.
10. Poole, R.W. 1974. An Introduction to Quantitative Ecology. McGraw-Hill, New York. 532 pp.
11. Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A List of Common and Scientific Names of Fishes from the United States and Canada. Amer. Fisheries Society, Special Pub. #12. 174 pp.
12. Smith, P.W. 1979. The Fishes of Illinois. Univ. of Illinois Press, Urbana, Illinois. 314 pp.
13. Trautman, M.B. 1981. The Fishes of Ohio. Ohio State Univ. Press, Columbus, Ohio. 782 pp.
14. Wayne, W.S. 1956. Thickness of Drift and bedrock physiography of Indiana north of the Wisconsin glacial boundary. Ind. Dept. Conserv. Geol. Surv. Rept. of Progress, No. 7, 70 pp.

The Quaternary Distribution of the Eastern Woodrat, *Neotoma floridana*, in Indiana

Ronald L. Richards
Indiana State Museum and Historic Sites
202 North Alabama Street
Indianapolis, Indiana 46204

Introduction

The eastern woodrat (*Neotoma floridana*) was first noted in Indiana in Wyandotte Cave, Crawford County in the 1870s (5,27). Twenty years later Blatchely noted that those woodrats had disappeared (3). The first Indiana specimens were taken by Hickie and Harrison around 1930 from a small cave one mile east of Wyandotte Cave, and from Rat Cave, Tobacco Landing, both in Harrison County (19). In the 1940s Kirkpatrick and Conaway recovered additional evidence of living woodrats along the Ohio River in Harrison County, as well as apparent woodrat lodge debris (piles of sticks with nuts, bones and rocks), though no specimens, in what was apparently Stroud cave, Valeene Quadrangle, Orange County (22). Jackson recalled when he and Robert Louden had, many years earlier, explored a 35 foot deep pit near the Harrison-Crawford county line, "passing through the largest concentration of cave rats" that he had ever seen (20). (The cave is among the many located in sections 26 and 27, T3S, R2E in Harrison and Crawford Counties, respectively, near where Hickie and Harrison, 19, collected their specimens.) In the 1950s archaeological investigation of rockshelters and paleontological studies of cave faunas revealed woodrat remains north of the present range in Missouri (31), Illinois (30), Indiana (1) and Ohio (12; Figure 1). The Indiana bones, from Sullivan Cave,

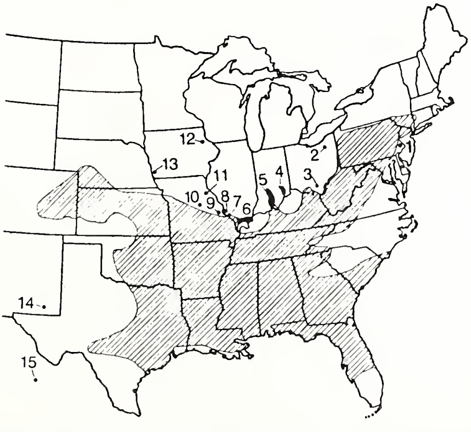


Figure 1. Fossil and sub-recent extralimital occurrence of *Neotoma floridana*. Hatched: Modern range, generally after Hall (17), with updated detail in Indiana (6), Ohio (21) and Kentucky (2). Numbers: extralimital localities (with references): 1. Durham Cave, Bucks Co., PA (23); 2. Twinsburg Rock Shelter, Summit Co., OH., (12); 3. Canter Caves, Jackson Co., OH (12); 4. Southeastern karst, IN (this report); 5. South-central karst, IN (this report); 6. Southern IL (26); 7. Modoc Rock Shelter, Randolph Co., IL (28); 8. Meyer Cave, Monroe Co., IL (29,30); 9. Crankshaft Cave, Jefferson Co., MO (34); 10. Brynjulfson Caves, Boone Co., MO (33); 11. Jerry Long Cave, Ralls Co., MO (31); 12. Willard Cave, Delaware Co., IA (9); 13. Pleasant Ridge local fauna, Mills Co., IA (10); 14. Dry Cave, Eddy Co., NM (18); 15. Jimenez Cave, Chihuahua, Mexico (18).

Lawrence County were associated with remains of such extirpated (historically exterminated) mammals as the porcupine, spotted skunk and elk, and clearly indicated a much more extensive past distribution of the woodrat in Indiana. Richards (35) recorded woodrat bones from several counties in south-central, and one county (Jennings) in southeastern Indiana, many associated with remains of resident as well as of extirpated species. Mumford and Whitaker (24) gave an extensive review of the Indiana woodrat. Richards (36) noted extralimital (occurring out of the historic range) woodrat remains from Shelby, Jennings and Jefferson Counties. Cudmore (6) made an extensive search for active and inactive woodrat sites in south-central Indiana, locating living woodrats only in the Ohio River region of Harrison and Crawford Counties (Figure 2). He found that extensive limestone bluffs which had some southern facing component harbored the greatest concentration of woodrats, and that there was a positive correlation between the density of juniper (*Juniperus virginiana*) and the density of woodrats. Wet caves did not harbor woodrats, nor did sandstone outcroppings provide suitable denning opportunities. In contrast, there are active woodrat populations in some of the sandstone bluffs in southwestern Illinois (26), and they are "particularly common" in the sandstone cliffs of the Cumberland Plateau of Kentucky (2).

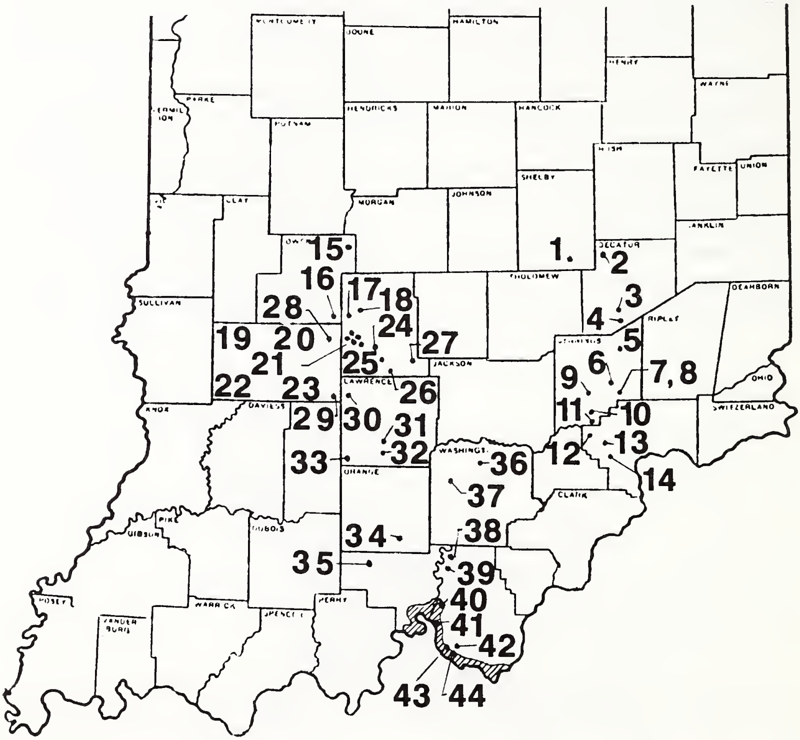


FIGURE 2. Quaternary distribution of the eastern woodrat, *Neotoma floridana*, in Indiana. Modern range (hatched) after Cudmore (6). Fossil and sub-recent localities numbered as in Table 1.

Methods

The objective was to determine the distribution of past woodrat activity in Indiana, with special emphasis upon the poorly investigated karst area of southeastern Indiana. This involved the location and recovery of woodrat bones from cave deposits. Cave locations were acquired from the "Indiana State Cave List", with caves on the periphery of both karst areas, particularly those of the southeastern, receiving investigative priority. This insured examination of marginal woodrat habitat, with possibility for the greatest range extension. Caves more centrally located in the karst areas were also investigated; I attempted to recover one woodrat bone locality per quadrangle map as time permitted. Low, water crawls were only partially investigated, unless larger, dry cavern development was anticipated beyond. Several small caves were investigated in northern Indiana (Wabash, Tippecanoe and Fountain Counties); I recovered very sparse bone accumulations, and no woodrat. Ledges and cavities of the massive sandstone outcroppings (Mansfield fm) prevalent in Martin and Fountain Counties were not examined.

Woodrat indicators sought were areas of disintegrated wood and vegetation, concentrations of nuts and seeds, and especially rodent-gnawed bone fragments, usually anticipated upon ledges, sometimes near cave ceilings, and in floor silt/clay deposits, within both wet and dry cave passages. Deposits appearing possibly productive were sampled or removed entirely (e.g. thin veneers of sediment upon ledges) and later washed through 1.2 mm mesh screen. This concentrate was examined under 15X magnification, and the faunal/floral remains removed for study. Materials from the field study, largely of undescribed faunas, are presently on file with the author.

Results

Woodrat remains from 48 minimum individuals (MNI) were recovered from 13 caves in Shelby, Decatur, Jennings and Jefferson Counties in southeastern Indiana, with remains of 60 MNI collected from 19 caves in Owen, Monroe, Greene, Lawrence, Crawford, Washington and Harrison Counties in south-central Indiana (Table 1). With the previous woodrat localities of Richards (35), the Harrodsburg Crevice (32), the Indun Rockshelter (Richards and Munson, in prep.) and Fair-to-Middlin Well (37) there are now 30 woodrat bone localities recorded in south-central and 14 localities in southeastern Indiana (Figure 2).

Most of the caves in the southeastern karst area were relatively small, often stream-bearing passages in the lowlands bordering streams and rivers. As in southern Illinois (26), these outcrop-lined tributaries provided natural avenues for woodrat dispersal. These caves commonly contained organic deposits composed of splintered bone (usually of mice, small fish, birds and eastern cottontail), fish scales, sphaerid clam valves, aquatic snails, crayfish and insect exoskeletons, and seeds, indicating areas of disintegrated carnivore scat. Fox, mink, striped skunk and especially raccoon are known to enter caves (24), the last routinely entering in search of bats (25). These carnivore generated bone deposits, often on ledges and perched clay banks, did not usually contain woodrat bones. Other niches and crevices perched above cave floors often contained concentrations of seeds (especially of hackberry), and occasionally small vertebrate bones, marking white-footed mouse (*Peromyscus leucopus*) dens. These deposits rarely contained woodrat bones or teeth.

The northwestern caves of the south-central karst area (Putnam and northern Owen Counties) were relatively small, often low, wet crawlways, and usually devoid of bone accumulations. Some of the drier caves, however, had crawlways floored with abundant dessicated (sometimes fresh) scat, reflecting heavy carnivore traffic. These areas, also, were not productive for woodrat bones.

In the caves more centrally located within the karst areas, woodrat bones could

TABLE 1. Indiana *Neotoma floridana* bone localities, with important associated taxa.[1]

	Cave/Site	Quadrangle	County	MNI	Important Associated Taxa
*1.	Flat Rock Cave	Waldron	Shelby	1	***Crotalus horridus*, timber rattlesnake; *Lynx* sp. (*Lynx rufus*, bobcat, suggested by modern distribution)
*2.	Dead Man's Cave	Adams	Decatur	2	**timber rattlesnake
*3.	Horsethief Cave	Westport	Decatur	2	bobcat (see * 1)
*4.	Faultz Cave	Westport	Decatur	5	*Castor canadensis*, beaver
*5.	Muscatatuck Caverns I	Butlerville	Jennings	12	--------
*6.	Henchman Cave	Vernon	Jennings	7	beaver; *Ursus americanus*, black bear
*7.	Crawl Cave	Vernon	Jennings	5	beaver; black bear
*8.	Cox Cave	Vernon	Jennings	1	--------
9.	Cave near North Vernon	Hayden	Jennings	3	in surficial sediments: black bear; *Cervus elaphus*, elk
				1	in lower reddish stratum: ***Phenacomys* cf. *P. intermedius*, heather vole.
*10.	Jesse Tate Cave	Deputy	Jennings	8	*Canis* cf. *C. lupus*, timber wolf
*11.	Paris Spring Cave	Deputy	Jennings	1	--------
*12.	Deputy Cave	Deputy	Jefferson	1	--------
*13.	Wilson Cave	Volga	Jefferson	2	--------
*14.	Kent Cave	Kent	Jefferson	1	--------
*15.	Porter's Cave	Quincy	Owen	1	--------
16.	Hidden Pit Cave	Whitehall	Owen	3	--------
17.	Freeman's Pit	Whitehall	Monroe	18	black bear; ***Spilogale putorius*, spotted skunk; *Erethizon dorsatum*, porcupine.
*18.	Galyan Pit Cave	Whitehall	Monroe	1	--------
19.	Brinegar Cave	Stanford	Monroe	2	black bear
*20.	Showcase Pit Cave	Stanford	Monroe	3	black bear; porcupine
21.	Bee Tree Cave	Stanford	Monroe	3	porcupine
*22.	Small Dull Cave	Stanford	Monroe	1	--------
*23.	Rock East Cave	Stanford	Monroe	1	--------
24.	Anderson Pit Cave	Clear Creek	Monroe	14	in main den: +*Dasypus bellus*, beautiful armadillo; black bear; ***Oryzomys palustris*, rice rat; ***Parascalops breweri*, hairy-tailed mole; ***Spermophilus tridecemlineatus*, thirteen-lined

				ground squirrel; ***Tamiasciurus hudsonius*, red squirrel; ***Opheodrys vernalis*, smooth green snake; +*Ectopistes migratorius*, passenger pigeon.
			5	in four other deposits, one with porcupine, another with a human (*Homo sapiens*) molar.
25. Harrodsburg Crevice	Clear Creek	Monroe	12	+*Canis* cf. *C. dirus*, dire wolf; +*Smilodon fatalis*, sabertooth cat; +*Panthera onca augusta*, jaguar; +*Equus* cf. *E. complicatus*, horse; +*Platygonus* cf. *P. vetus* (= *cumberlandensis*), Leidy's peccary; **hairy-tailed mole; ***Geomys* cf. *G. bursarius*, plains pocket gopher; **Spotted skunk; black bear; bobcat
*26. Indun Rockshelter	Clear Creek	Monroe	2	**Spotted skunk; +*Mylohus* sp., long-nosed peccary
*27. Patton Cave	Allens Creek	Monroe	3	--------
*28. Mill Cave	Stanford	Greene	1	--------
*29. Batey Cave	Owensburg	Greene	2	black bear; beaver
30. Sullivan Cave	Owensburg	Lawrence	7	in ledge den: black bear; **spotted skunk; porcupine; elk (last by Bader and Hall (1) only).
			16	in floor deposit: +beautiful armadillo; **spotted skunk; **heather vole; ***Clethrionomys gapperi*, red-backed vole; **plains pocket gopher; **thirteen-lined ground squirrel; black bear; porcupine.
31. Carcass Crypt Pit Cave	Bedford West	Lawrence	4	in wall den: black bear; **spotted skunk
			6	in floor deposits: **hairy-tailed mole; **spotted skunk; black bear; bobcat; porcupine.
*32. McCart Pit Cave	Georgia	Lawrence	2	black bear
*33. Connelly Cave	Huron	Lawrence	2	--------
34. Stroud Cave	Valeene	Orange	1	porcupine
*35. Megenity Peccary Cave	Taswell	Crawford	3	+*Platygonus compressus*, Flat-headed Peccary; ***Martes pennanti*, fisher; **Plains Pocket Gopher. (collection in progress)
*36. Suicide Cave	Kossuth	Washington	6	--------
*37. Waterfall Cave	Smedley	Washington	6	--------
*38. Gibbs Pit	Fredericksburg	Harrison	2	--------
*39. King Leo Pit Cave	Depauw	Harrison	9	**spotted skunk; black bear; elk
*40. Devil's Staircase Pit Cave	Leavenworth	Harrison	1	--------
*41. Passenger Pigeon Cave	Leavenworth	Harrison	10	**cf. spotted skunk; **rice rat; +passenger pigeon; beaver.
*42. Horse Pit Cave	Mauckport	Harrison	1	--------
43. N. Jim Cave	Mauckport	Harrison	4	**plains pocket gopher; **red-backed vole; **red squirrel
44. Fair-to-Middl'in Well Pit	Mauckport	Harrison	5	**spotted skunk; black bear

---

[1] *, new woodrat bone localities; +, extinct; **, extralimital; others listed are extirpated. MNI, *Neotoma*, minimum number of individuals.

usually be recovered from deposits that contained rodent-gnawed larger bone fragments (usually of White-tailed deer), located in wall niches and crevices, on ledges, and in general bone accumulations on dry cave floors. These deposits occurred in stream-bearing as well as dry passages in both walk-in and vertical pit entrance caves.

Discussion

It appears that the woodrat once occurred in suitable habitat throughout most of Indiana's karst area. Small caves on the peripheries of the karst areas apparently do not provide extensive denning possibilities, and, with often discontinuous bluff outcroppings for dispersal, supported lower densities of woodrats. In addition, heavy carnivore traffic in these small caves leaves the woodrat particularly susceptible to predation. These confrontations would appear to be less frequent in the larger, more centrally located caves, where greater vertical development of rooms and passage proliferation provide for more obscure woodrat denning.

Southern Illinois woodrat populations have undergone dramatic range reductions within historic time, perhaps due to abnormally cold winters with greater than average snowfall (26). Mortality was the heaviest in small, isolated populations in marginal habitat. Juterbock noted that the cached greens of Ohio woodrats used for winter food was often depleted in January or February (21). If, due to low winter temperatures and extended periods of snow cover, fresh buds and greens were not available, winter mortality might be higher than normal. This mortality would be felt especially in small populations due to the woodrat's low reproductive rate (two or three young/litter; one or two litters/year), and territoriality (young leaving den to establish home range become vulnerable for predation). She noted that juniper was sometimes the only winter food available to the woodrat. Cudmore noted the high association of juniper with active Indiana woodrat populations (6). Juniper prefers calcareous soils, and is common in much of the unglaciated region of southern Indiana (7). Notably, juniper thrives in areas where the woodrat no longer occurs, suggesting that winter access to juniper may not be a dominant factor in population survival.

The association of woodrat with such extralimital boreal forms as the heather (*Phenacomys* cf. *P. intermedius*) and red-backed (*Clethrionomys gapperi*) voles in Jennings, Lawrence and Harrison County cave deposits (38; Table 1), suggests that the woodrat was not particularly sensitive to at least some of the cooler glacial environments present in southern Indiana some 12,000 years ago. The woodrat was also part of the cool, Late Pleistocene fauna at New Paris No. 4 Sink, Pennsylvania (15), Clark's Cave, Virginia (16) and Robinson Cave, Tennessee (14). Cool, glacial environments may not have had a pronounced impact upon winter food stores, because of the greater abundance and diversity of winter greens available from the coniferous (8) forest.

The fossil occurence of the woodrat, and its relatively northern distribution in the eastern and western portions of its modern range suggest that lack of suitable habitat, rather than climatic conditions *per se* may be a limiting factor to the northern distribution of the woodrat (15, 16).

In Indiana, the woodrat has been recovered from deposits as early as the Sangamonian (last) interglacial at the Harrodsburg Crevice, and as late as 2,315 ± 65 years before present in Freeman's Pit, both in Monroe County. Notably, the woodrat evacuated over 95% of its former Indiana range sometime between 2000 years ago and the European settlement of the state.

Iowa has produced at least two extralimital woodrat localities with Late Holocene dates: the Pleasant ridge local fauna, Mills County (1450 years before present; 10), and Willard Cave, Delaware County (post-Altithermal; 9). The woodrat depopulation of southern Illinois, in contrast has been relatively recent, with dramatic range reductions perhaps in the early 1900s and in the 1930s-1950s, as evidenced by corn cobs, cow dung, broken glass and rusty nails in extralimital woodrat middens near human dwellings (26). Common within the cliff and cave habitat in the Ridge and Valley province of Tennessee, the woodrat apparently does not persist in settled areas (13).

There is thus far a lack of European materials in the extralimital woodrat middens in Indiana. Nor has the woodrat been associated with bones of the black or Norway rats (*Rattus* sp.), the house mouse (*Mus musculus*), or with rodent gnawed remains of domestic livestock or poultry. (Teeth of *Rattus* and *Neotoma* recovered from a deposit in Waterfall Cave, Washington County, could not be shown to be contemporary, considering the bulk method of recovery.)

The cause of the Late Holocene and historic depopulation of the woodrat from the northern periphery of its range in the midwest, whether related to severe winters, their effect upon winter food availability, or the effect of human contact in marginal habitat, is unclear.

Considering that endemic populations of such animals as the smoky (*Sorex fumeus*) and pygmy (*Sorex hoyi*) shrews (4), and the cottonmouth (*Agkistrodon piscivorus*; 11) were first recorded in Indiana in 1981 and 1983, respectively, it is understandable that small disjunct populations of the nocturnally active woodrat might exist undetected in Indiana's karst area. Sightings of rat-like animals have been reported in Owen (Hopper Cave, Cataract Quad.), Monroe (Salamander Cave and Studebaker Pit, Whitehall Quad.; Bee Tree Cave, Stanford Quad.), Lawrence (Donaldson's Cave, Mitchell Quad.), Washington (Endless Cavern and Lamplighter Cave, Campbellsburg Quad.) and Crawford (Wildcat Cave, Leavenworth Quad.) Counties within the past thirty years. Most of these observations can probably be attributed to glimpses of the white-footed mouse, which does den within the caves (24), and has been observed on numerous instances by the author, occasionally while scampering from its nest cup. Night investigation of these and other cave areas might provide records of disjunct woodrat colonies.

Acknowledgments

The Indiana State Museum Society kindly provided a grant to support part of the southeastern Indiana field work. Gordon Lindamood and Jim Riley supplied lists of cave locations. Dave Rieger produced Figures 1 and 2. I am indebted especially to Ted Sparks and also Gordon Lindamood, Dave Rieger, Richard Cornell, Howard Ely and many others for aid in the field.

Literature Cited

1. Bader, R.S. and J.S. Hall. 1960. Mammalian remains from an Indiana cave. J. Mammal. 41: 111-112.
2. Barbour, R.W. and W.H. Davis. 1974. Mammals of Kentucky. Univ. Press Kentucky, Lexington. 322 pp.
3. Blatchley, W.S. 1897. Indiana caves and their fauna. 21st Ann. Rept. Indiana Dept. Geol. Nat. Res.: 121-212.
4. Caldwell, R.S., C.K. Smith and J.O. Whitaker, Jr. 1982. First records of the Smoky Shrew, *Sorex fumeus*, and Pygmy Shrew, *Microsorex hoyi*, from Indiana. Proc. Indiana Acad. Sci. 91: 606-608.
5. Cope, E.D. 1872. Report on the Wyandotte Cave and its fauna. Third and Fourth Ann. Repts. Indiana Geol. Surv.: 157-182.
6. Cudmore, W.W. 1985. The present distribution and status of the Eastern Woodrat, *Neotoma floridana*, in Indiana. Proc. Indiana Acad. Sci. 94: 621-627.
7. Deam, C.C. 1940. Flora of Indiana. Indiana Dept. Conserv., Div. Forestry. 1236 pp.
8. Delcourt, P.A. and H.R. Delcourt. 1981. Vegetation maps for eastern North America: 40,000 years B.P. to the present, *in*: R.C. Romans (ed.), Geobotany II, p. 123-165. Plenum, New York.

9. Eshelman, R.E. 1971. The paleoecology of Willard Cave, Delaware County, Iowa. M.S. thesis, University of Iowa, Iowa City. 72 pp.
10. Fay, L.P. 1980. Mammals of the Garrett Farm and Pleasant Ridge local biotas (Holocene), Mills County, Iowa, *in*: Amer. Quat. Assoc., Sixth Bien. Mtg., Abstr. with Program: 74-75. Inst. for Quat. Stud., Univ. Maine, Orono.
11. Forsyth, B.J., C.D. Baker, T. Wiles and C. Weilbaker. 1985. Cottonmouth, *Agkistrodon piscivorus*, records from the Blue River and Potato Run in Harrison County, Indiana (Ohio River Drainage, USA). Proc. Indiana Acad. Sci. 94: 633-634.
12. Goslin, R.M. 1955. Animal remains from Ohio rock shelters. Ohio J. Sci. 55(6): 358-362.
13. Guilday, J.E., H.W. Hamilton, E. Anderson and P.W. Parmalee. 1978. The Baker Bluff Cave deposit, Tennessee, and the Late Pleistocene faunal gradient. Carnegie Mus. Nat. Hist. Bull. 11: 1-67.
14. Guilday, J.E., H.W. Hamilton and A.D. McCrady. 1969. The Pleistocene vertebrate fauna of Robinson Cave, Overton County, Tennessee. Palaeovertebrata 2: 25-75.
15. Guilday, J.E., P.S. Martin and A.D. McCrady. 1964. New Paris No. 4: A Pleistocene cave deposit in Bedford County, Pennsylvania. Natl. Speleol. Soc. Bull. 26: 121-194.
16. Guilday, J.E., P.W. Parmalee and H.W. Hamilton. 1977. The Clark's Cave bone deposit and the Late Pleistocene paleoecology of the central Appalachian Mountains of Virginia. Carnegie Mus. Nat. Hist. Bull. 2: 1-87.
17. Hall, E.R. 1981. The mammals of North America. 2nd ed. John Wiley and Sons, New York. 2 vols. 1181 pp.
18. Harris, A.H. 1984. *Neotoma* in the Late Pleistocene of New Mexico and Chihuahua. p. 164-178, *in*: H.H. Genoways and M.R. Dawson (eds.). Contributions in Quaternary Vertebrate Paleontology: A Volume in Memorial to John E. Guilday. Carnegie Mus. Nat. Hist. Spec. Publ. 8. 538 pp.
19. Hickie, P.F. and T. Harrison. 1930. The Alleghany wood rat in Indiana. Amer. Midl. Nat. 12: 169-174.
20. Jackson, G.F. 1972. Notes and News: Old timers fewer now. Natl. Speleol. Soc. News, 30(11): 151.
21. Juterbock, J.E. 1986. Eastern woodrat. Cincinnati Mus. Nat. Hist. Quart. 19(4): 5-8.
22. Kirkpatrick, C.M. and C.H. Conaway. 1948. Some notes on Indiana mammals. Amer. Midl. Nat. 39(1): 128-136.
23. Lundelius, E.L., Jr., R.W. Graham, E. Anderson, J.E. Guilday, J.A. Holman, D.W. Steadman and S.D. Webb. 1983. Terrestrial vertebrate faunas, p. 311-353, *in*: S.C. Porter (ed.), Late Quaternary environments of the United States: Vol. 1, The Late Pleistocene. Univ. Minnesota Press. Minneapolis. 407 pp.
24. Mumford, R.E. and J.O. Whitaker, Jr. 1982. Mammals of Indiana. Indiana University Press, Bloomington. 537 pp.
25. Munson, P.J. and J.H. Keith. 1984. Prehistoric raccoon predation on hibernating *Myotis*, Wyandotte Cave, Indiana. J. Mammal. 65(1): 152-155.
26. Nawrot, J.R. and W.D. Klimstra. 1976. Present and past distribution of the endangered southern Illinois woodrat (*Neotoma floridana illinoensis*). Nat. Hist. Misc. Chicago Acad. Sci. 196: 1-12.
27. Packard, A.S. 1888. The cave fauna of North America, with remarks on the anatomy of the brain and origin of the blind species. Mem. Nat. Acad. Sci. 4: 3-156.
28. Parmalee, P.W. 1959. Animal remains from the Modoc Rock Shelter site, Randolph County, Illinois, Appendix II, p. 61-65, *in*: M.L. Fowler. Summary report of Modoc Rock Shelter. Illinois State Mus. Rep. Invest. 8: 1-72.
29. Parmalee, P.W. 1967. A Recent cave bone deposit in southwestern Illinois. Natl. Speleol. Soc. Bull. 29(4): 119-147.

30. Parmalee, P.W., R.A. Bieri and R.K. Mohrman. 1961. Mammal remains from an Illinois cave. J. Mammal. 42(1): 119.
31. Parmalee, P.W. and K.W. Jacobson. 1959. Vertebrate remains from a Missouri cave. J. Mammal. 49(3): 401-405.
32. Parmalee, P.W., P.J. Munson and J.E. Guilday. 1978. The Pleistocene mammalian fauna of Harrodsburg Crevice, Monroe County, Indiana. Natl. Speleol. Soc. Bull. 40: 64-75.
33. Parmalee, P.W. and R.D. Oesch. 1972. Pleistocene and Recent faunas from the Brynjulfson caves, Missouri. Illinois State Mus. Rep. Invest. 25: 1-52.
34. Parmalee, P.W., R.D. Oesch and J.E. Guilday. 1969. Pleistocene and Recent vertebrate faunas from Crankshaft cave, Missouri, Illinois State Mus. Rep. Invest. 14: 1-37.
35. Richards, R.L. 1972. The woodrat in Indiana: Recent Fossils. Proc. Indiana Acad. Sci. 81: 370-375.
36. Richards, R.L. 1984. The Pleistocene vertebrate collection of the Indiana State Museum with a list of the extinct and extralocal Pleistocene vertebrates of Indiana. Proc. Indiana Acad. Sci. 93: 483-504.
37. Richards, R.L. 1984. It's the pits: explorer discovers black bear bones. Outdoor Indiana 49(7): 25-27.
38. Richards, R.L. 1986. Late Pleistocene remains of boreal voles (Genera *Phenacomys* and *Clethrionomys*) from southern Indiana caves. Proc. Indiana Acad. Sci. 95: 537-546.
39. Semken, H.A., Jr. 1984. Paleoecology of a Late Wisconsinan/Holocene micromammal sequence in Peccary Cave, northwestern Arkansas, p. 405-431, *in*: H.H. Genoways and M.R. Dawson (eds.), Contributions in Quaternary Vertebrate Paleontology: A Volume in Memorial to John E. Guilday. Carnegie Mus. Nat. Hist. Spec. Publ. 8. 538 pp.

Summer Fishes of Pigeon Creek Drainage

Susan J. Schultheis, Kenneth D. Berger, Rusty K. Yeager,
David M. Agee and Thomas H. Cervone
University of Southern Indiana
Evansville, Indiana 47712

Introduction

Pigeon Creek is geographically situated in unglaciated terrain of the Wabash Lowland Region (14) in southwestern Indiana. It flows for approximately 64 kilometers in a southerly direction through the counties of Gibson, Warrick, and Vanderburgh draining an area of 953 square kilometers (4) before entering the Ohio River (Figure 1). Elevations within

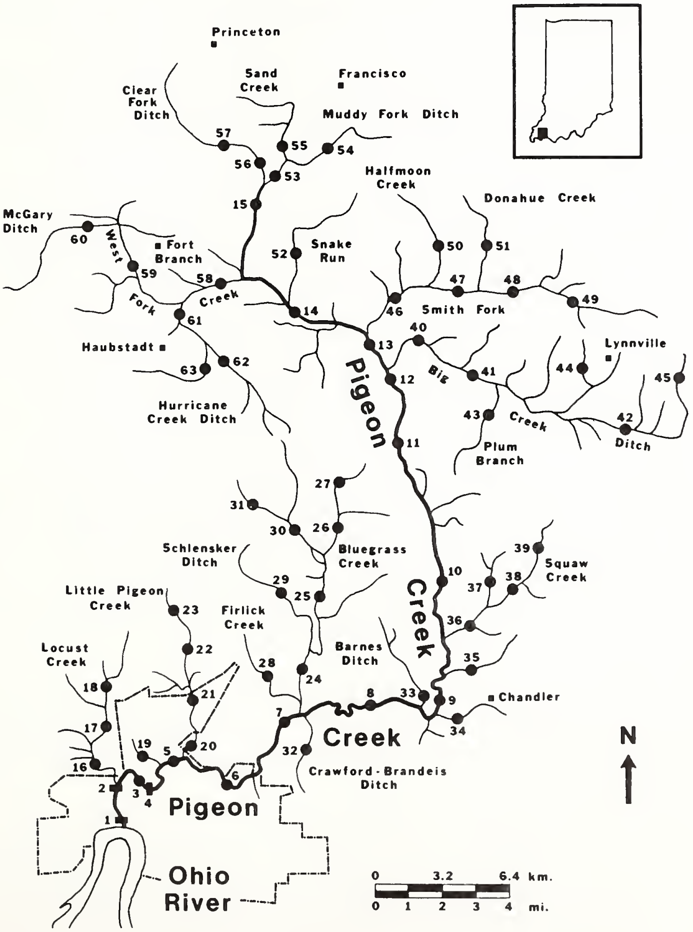


Figure 1. Map of Pigeon Creek depicting collecting stations (● - seined, ▮ - electroshocked), towns ( ), and the city limits of Evansville (—·—·—).

the drainage basin range from 110 to 152 meters above sea level. The major municipality along its course is Evansville.

Pigeon Creek is a slow-flowing, turbid stream. Its substrate is primarily deep calcitic to organic mud with some headwater tributaries displaying streambeds of gravel and sand. Its banks, margined for the most part by cottonwood, sycamore, silver maple, and box elder, are steep throughout its length with submerged downfall common near its mouth.

Pigeon Creek flows through three distinct land types. They are agricultural lands bordering its headwaters, coal mining lands in the middle region of the drainage, and the city of Evansville in the lower region. Pigeon Creek is classified as a legal drain, which allows for dredging and subsequent siltation.

Information on fishes in Pigeon Creek is lacking. The first known record of fishes in Pigeon Creek was in 1888 (5). That investigation sampled only the mouth of Pigeon Creek. In 1942, three stations were sampled within Pigeon Creek drainage (2). To our knowledge no other studies have been completed. Compounded with this lack of information, fish kills in the drainage are not uncommon. For these reasons, a fish study was warranted.

The purpose of this investigation was to provide base-line data on the type, distribution, relative abundance, and species diversity of fishes in Pigeon Creek drainage during the summer. A secondary objective was to compare the results of this study with those of 1942 (2).

Material and Methods

Sixty-three sites were sampled within the Pigeon Creek drainage (Figure 1) from 7 July to 4 August 1986. Fishes were collected using either singly or a combination of a bag seine (2 wings - 3.0 × 1.2 meters and bag - 1.2 × 1.2 meters of 1 cm diamond mesh), a 4.3 × 1.2 meter seine (0.5 cm square mesh), or a 1.7 × 1.1 meter seine (0.6 cm square mesh). Stations 1, 2, and 3 were sampled using a Type VI Electrofisher shocker. Fishes were shocked for 2-4 milliseconds at 8-10 amperes (VDC 420 and 560). Fishes were collected for 30 minutes and following capture were preserved in 10% formalin. Preserved specimens are presently housed within the University of Southern Indiana collection.

Species diversity was determined using the Shannon-Weaver function (H′): $H' = C/N\ (N \log_{10} N - \Sigma n_i \log_{10} n_i)$, where $C = 3.32$ (the constant for conversions of logarithms from base 10 to base 2); N = the total number of individuals in the population; and n_i = the number of individuals of a particular species (3). Results are independent of sample size (10).

Fishes were identified to species using standard references (1,7,9,12,13) and all scientific names herein reported are acceptable nomenclature (11).

Results

In this investigation, 39 species of fish from 14 families were collected in Pigeon Creek drainage. Table 1 lists these fishes, their distribution and relative abundance in the drainage. Figure 1 depicts the stations sampled, while Appendix A identifies the location of each collecting site.

The tributaries of Pigeon Creek yielded more fishes per station than the main stream (Table 2; $t = 1.88$; $df = 61$; $p < .05$). Adults accounted for the majority of this intra-drainage difference ($t = 1.69$; $df = 61$; $p < .05$), while young showed a tendency towards greater numbers in the tributaries ($t = 1.36$; $df = 61$; $p < .10$). Of the 39 species collected, young of 24 species (61.5%) were represented, comprising 31% of the total catch.

The distribution of fishes in the drainage showed 6 species from exclusively the main stream including the mouths of larger tributaries. They were the bowfin, gizzard shad, mississippi silvery minnow, emerald shiner, flier, and white crappie. The warmouth and

TABLE 1. List of fishes, their distribution and relative abundance in Pigeon Creek drainage. The number before the parenthesis represents the site followed by the number of individuals collected or seen (*) in parentheses. Followed by a semicolon are the % of total catch and % occurrence (# of stations/63 stations) for each species.

Lepisosteidae

Lepisosteus platostomus (Shortnose Gar) — 2(1); <0.1, 1.6

Amiidae

Amia calva (Bowfin) — 2(1), 34(1); <0.1, 3.2

Clupeidae

Dorosoma cepedianum (Gizzard Shad) — 1(15), 2(3), 3(34), 4(25), 5(5), 6(1), 7(10), 8(2), 14(1), 24(3), 34(5); 1.5, 17.5

Esocidae

Esox americanus (Grass Pickerel) — 26(1), 33(2), 35(1), 41(2), 43(1); 0.1, 7.9

Cyprinidae

Campostoma anomalum (Central Stoneroller) — 47(1), 48(7), 49(1); 0.1, 4.8

Cyprinus carpio (Common Carp) — 2(9), 4(3), 7(1), 8(1), 14(1), 32(2), 35(2), 57(2), 58(4), 60(1); 0.4, 15.9

Ericymba buccata (Silverjaw Minnow) — 5(5), 13(1), 14(4), 15(3), 18(16), 21(13), 22(85), 23(22), 25(1), 28(2), 29(60), 42(3), 47(134), 48(58), 49(37), 50(27), 54(8), 55(61), 56(53), 57(39), 61(7), 63(7); 9.6, 34.9

Hybognathus nuchalis (Mississippi Silvery Minnow) — 5(2), 20(1); <0.1, 3.2

Notemigonus crysoleucas (Golden Shiner) — 7(7), 12(2), 22(1), 30(11), 31(8), 41(106), 42(2), 45(2), 48(2), 50(1), 60(2); 2.1, 17.5

Notropis atherinoides (Emerald Shiner) — 3(70), 5(213), 20(1); 4.2, 4.8

Notropis umbratilis (Redfin Shiner) — 8(2), 9(5), 12(23), 13(3), 14(5), 15(40), 40(4), 47(3), 52(12), 53(2), 54(34), 55(2), 56(11), 57(12), 58(17), 59(173), 60(38), 61(260), 62(2), 63(85); 10.9, 31.7

Phenacobius mirabilis (Suckermouth Minnow) — 5(2), 12(7), 13(2), 15(17), 18(1), 21(6), 22(3), 25(1), 36(1), 37(4), 38(2), 40(2), 47(10), 48(16), 50(2), 56(37), 57(1), 59(5), 61(3), 63(7), 1.9, 31.7

Pimephales notatus (Bluntnose Minnow) — 3(1), 5(5), 7(4), 9(2), 14(10), 15(11), 17(5), 18(3), 19(35), 21(42), 22(16), 23(13), 24(3), 25(8), 27(1), 28(1), 29(8), 30(2), 31(14), 32(105), 33(4), 36(1), 47(1), 48(1), 49(1), 50(4), 52(8), 53(2), 54(19), 55(12), 56(25), 57(41), 58(14), 59(10), 60(5), 61(36), 62(16), 63(105); 8.8, 60.3

Pimephales promelas (Fathead Minnow) — 7(6), 12(1), 13(1), 14(45), 19(1), 23(1), 25(5), 27(1), 50(1), 52(12), 54(10), 55(1), 56(4), 57(6), 58(39), 59(8), 60(9), 61(38), 62(191), 63(244); 9.2, 31.7

Semotilus atromaculatus (Creek Chub) — 15(7), 17(3), 18(9), 19(3), 21(1), 22(84), 23(12), 25(3), 26(35), 27(36), 28(8), 29(9), 30(2), 31(1), 32(4), 33(5), 35(1), 36(1), 37(32), 38(31), 42(12), 43(12), 45(8), 47(19), 48(20), 49(14), 50(45), 51(29), 52(26), 54(32), 55(34), 56(44), 57(42), 58(3), 59(87), 60(1), 61(133), 62(347), 63(59); 18.6, 61.9

Catostomidae

Carpiodes cyprinus (Quillback) — 12(1); <0.1, 1.6

Catostomus commersoni (White Sucker) — 24(1); <0.1, 1.6

Erimyzon oblongus (Creek Chubsucker) — 17(1), 25(1), 31(3); 0.1, 4.8

Ictiobus bubalus (Smallmouth Buffalo) — 1(1); <0.1, 1.6

Ictiobus niger (Black Buffalo) — 1(3); <0.1, 1.6

Ictaluridae

Ictalurus melas (Black Bullhead) — 7(35), 24(1), 27(78), 30(77), 32(6), 34(5), 35(1), 39(2), 52(1), 54(3), 62(2); 3.1, 17.5

Ictalurus natalis (Yellow Bullhead) — 7(3), 13(1), 26(1), 32(6), 33(1), 35(4), 54(1), 57(2), 58(4), 62(4); 0.4, 15.9

Ictalurus punctatus (Channel Catfish) — 5(1), 6(3), 13(1), 14(1), 36(1), 38(5), 39(1), 58(7); 0.3, 12.7

Aphredoderidae

Aphredoderus sayanus (Pirate Perch) — 7(2), 8(1), 21(1), 24(3), 25(8), 26(2), 30(6), 34(1), 41(2), 53(1), 54(1), 56(1); 0.4, 19.0

Cyprinodontidae

Fundulus notatus (Blackstripe Topminnow) — 5(1), 7(2), 9(1), 11(2), 12(1), 13(1), 14(9), 15(15), 16(*), 17(12), 18(34), 21(12), 22(4), 23(5), 24(1), 25(5), 26(5), 27(42), 28(13), 30(1), 31(11), 32(13), 33(23), 34(8), 35(14), 36(10), 37(5), 38(13), 39(13), 42(53), 43(9), 44(16), 45(4), 46(7), 47(28), 48(19), 49(11), 50(44), 51(5), 53(4), 54(55), 55(36), 56(15), 57(4), 58(12), 59(6), 60(16), 61(5), 62(1), 63(18); 9.6, 79.4

Poeciliidae

Gambusia affinis (Mosquitofish) — 1(*), 7(5), 8(7), 11(4), 14(1), 20(1), 21(13), 24(5), 25(4), 28(2), 32(65), 33(19), 35(1), 50(1), 55(1), 56(4); 2.0, 25.4

Percichthyidae

Morone chrysops (White Bass) — 1(6); 0.1, 1.6

Centrarchidae

Centrarchus macropterus (Flier) — 7(1), 10(5); 0.1, 3.2

Lepomis cyanellus (Green Sunfish) — 4(2), 6(2), 7(20), 8(2), 9(1), 10(1), 14(1), 15(2), 17(1), 19(3), 21(11), 22(7), 23(1), 24(21), 25(18), 26(13), 27(1), 28(2), 29(1), 30(1), 31(2), 32(8), 33(15), 35(9), 36(8), 37(109), 38(40), 39(119), 41(5), 42(3), 44(4), 45(2), 47(3), 48(15), 49(20), 50(8), 51(8), 52(5), 53(2), 54(13), 56(1), 58(1), 59(2), 60(1), 61(7), 62(3), 63(1); 7.8, 74.6

TABLE 1 (continued)

Lepomis gibbosus (Pumpkinseed) — 10(1), 23(1), 30(1), 34(2), 44(1), 45(1), 47(1); 0.1, 11.1

Lepomis gulosus (Warmouth) . 7(12), 10(3), 11(4), 34(2), 49(1); 0.3, 7.9

Lepomis humilis (Orangespotted Sunfish) — 34(2); <0.1, 1.6

Lepomis macrochirus (Bluegill) — 7(29), 8(2), 9(2), 10(11), 11(1), 14(2), 17(12), 18(3), 20(3), 21(80), 22(35), 23(19), 24(2), 25(2), 28(2), 29(1), 30(6), 31(2) 33(1), 34(9), 35(7), 36(2), 37(9), 38(4), 39(16), 42(1), 43(57), 44(9), 45(7), 46(18), 48(3), 49(4), 50(8), 51(9), 53(1), 54(6), 63(2); 5.7, 58.7

Lepomis megalotis (Longear Sunfish) — 15(5), 17(1), 23(1), 30(1), 36(1), 37(1), 38(1), 39(1), 42(1), 43(3), 45(2), 46(6), 48(14), 49(2), 54(1), 56(3), 58(1), 60(9), 61(3), 63(3); 0.9, 30.2

Micropterus punctulatus (Spotted Bass) — 11(1), 14(1), 17(2), 21(3), 25(2), 29(4), 30(1), 31(1), 32(1), 35(7), 39(1), 43(1), 44(9), 45(1), 47(1), 48(9), 49(2), 50(2), 53(1), 54(2), 57(2); 0.8, 33.3

Pomoxis annularis (White Crappie) — 7(1), 9(1), 14(1), 34(5), 53(1); 0.1, 6.3

Pomoxis nigromaculatus (Black Crappie) — 10(2), 11(3), 12(1), 34(6), 49(1); 0.2, 7.9

Percidae

Etheostoma gracile (Slough Darter) — 7(1), 24(5), 35(2), 36(4), 37(7); 0.3, 7.9

Sciaenidae

Aplodinotus grunniens (Freshwater Drum) — 5(2); <0.1, 1.6

APPENDIX A. Location of collecting stations in Pigeon Creek drainage, Indiana.

Station	Location
1	Vand. Co., Pigeon Twp., PIGEON CREEK — Columbia St. Bridge (Evansville S. Quad.: T6S, R11W, S24)
2	Vand. Co., Pigeon/Center Twp., PIGEON CREEK — Confluence with Locust Creek (Evansville S. Quad.: T6S, R11W, S13)
3,4	Vand. Co., Pigeon/Center Twp., PIGEON CREEK — First Ave. Bridge (Evansville S. Quad.: T6S, R10W, S18)
5	Vand. Co., Center/Knight Twp., PIGEON CREEK — Stringtown Rd. Bridge (Evansville N. Quad.: T6S, R10W, S8)
6	Vand. Co., Center/Knight Twp., PIGEON CREEK — Oak Hill Rd. Bridge (Evansville S. Quad.: T6S, R10W, S15)
7	Vand. Co., Center/Knight Twp., PIGEON CREEK — N. Green River Rd. Bridge (Daylight Quad.: T6S, R10W, S1/2)
8	Warrick Co., Ohio Twp., PIGEON CREEK — W. 1025 Rd. Bridge (Daylight Quad.: T5S, R9W, S32)
9	Warrick Co., Campbell/Ohio Twp., PIGEON CREEK — N. 50 Rd. Bridge (Daylight Quad.: T5S, R9W, S34)
10	Warrick Co., Campbell Twp., PIGEON CREEK — Booneville-New Harmony Rd. Bridge (Daylight Quad.: T5S, R9W, S10)
11	Warrick Co., Greer Twp., PIGEON CREEK — N. 875 Rd. Bridge (Elberfeld Quad.: T4S, R9W, S21)
12	Warrick Co., Greer Twp., PIGEON CREEK — Highway 68 Bridge (Elberfeld Quad.: T4S, R9W, S4)
13	Gibson Co., Barton Twp., PIGEON CREEK — Highway 57 Bridge (Elberfeld Quad.: T3S, R9W, S32)
14	Gibson Co., Union Twp., PIGEON CREEK — N. 1350 Rd. Bridge (Elberfeld Quad.: T3S, R10W, S25/26)
15	Gibson Co., Union Twp., PIGEON CREEK — N. 1650 Rd. Bridge (Princeton Quad.: T35, R10W, S10)
16	Vand. Co., Perry/German Twp., LOCUST CREEK — Allen Lane Bridge (Evansville N. Quad.: T6S, R11W, S11/14))
17	Vand. Co., Center Twp., LOCUST CREEK — Mill Rd. Bridge (Evansville N. Quad.: T6S, R11W, S1/12)
18	Vand. Co., Center Twp., LOCUST CREEK — Mohr Rd. Bridge E. of N.Y. Central Railroad Tracks (Evansville N. Quad.: T5S, R11W, S25/36)
19	Vand. Co., Center Twp., UNNAMED TRIB. — North Park, 200 yds. S. of Buena Vista Rd. (Evansville N. Quad.: T6S, R10W, S7)
20	Vand. Co., Center Twp., LITTLE PIGEON CREEK — Kentucky Ave. Bridge (Evansville N. Quad.: T6S, R10W, S8)
21	Vand. Co., Center Twp., LITTLE PIGEON CREEK — Old Petersburg Rd. Bridge (Evansville N. Quad.: T5S, R10W, S33)
22	Vand. Co., Center Twp., LITTLE PIGEON CREEK — Mt. Pleasant Rd. Bridge (Evansville N. Quad.: T5S, R10W, S29)
23	Vand. Co., Center/Scott Twp., LITTLE PIGEON CREEK — Hillsdale Rd. Bridge (Evansville N. Quad.: T5S, R10W, S7/20)
24	Vand. Co., Center Twp., BLUEGRASS CREEK — Millersburg Rd. Bridge (Daylight Quad: T5S, R10W, S25/36)
25	Vand. Co., Scott Twp., BLUEGRASS CREEK — County Line Rd. Bridge (Daylight Quad.: T5S, R10W, S13/18)
26	Warrick Co., Campbell Twp., BLUEGRASS CREEK — N. 600 Rd. Bridge (Daylight Quad.: T4S/T5S, R9W, S6/31)
27	Warrick Co., Greer Twp., BLUEGRASS CREEK — N. 750 Rd. Bridge (Elberfeld Quad.: T4S, R9W, S30)

Station	Location
28	Vand. Co., Center Twp., FIRLICK CREEK — Millersburg Rd. Bridge (Evansville N. Quad.: T5S, R10W, S26/35)
29	Vand. Co., Scott Twp., SCHLENSKER DITCH — Highway 57 Bridge (Daylight Quad.: T5S, R10W, S14)
30	Vand. Co., Scott Twp., UNNAMED TRIB. OF BLUEGRASS CREEK — Old Petersburg Rd. Bridge (Daylight Quad.: T4S, R10W, S35/36)
31	Vand. Co., Scott Twp., UNNAMED TRIB. OF BLUEGRASS CREEK — Volkman Rd. Bridge (Haubstadt Quad.: T4S, R10W, S35)
32	Vand. Co., Knight Twp., CRAWFORD-BRANDEIS DITCH — Hirsch Rd. Bridge (Daylight Quad.: T6S, R10W, S1/12)
33	Warrick Co., Campbell Twp., BARNES DITCH — N. 50 Rd. Bridge (Daylight Quad.: T5S, R9W, S34)
34	Warrick Co., Ohio Twp., STOLLBERG DITCH — Highway 62 Bridge (Daylight Quad.: T5S, R9W, S35)
35	Warrick Co., Campbell Twp., UNNAMED TRIB. — W. 700 Rd. Bridge (Daylight Quad.: T5S, R9W, S25/26)
36	Warrick Co., Campbell Twp., SQUAW CREEK — W. 700 Rd. Bridge (Daylight Quad.: T5S, R9W, S23/24)
37	Warrick Co., Campbell Twp., N. TRIB. OF SQUAW CREEK — N. 400 Rd. Bridge (Booneville Quad.: T5S, R9W, S12/13)
38	Warrick Co., Campbell Twp., SQUAW CREEK — N. 400 Rd. Bridge (Booneville Quad.: T5S, R8W, S7/18)
39	Vand. Co., Boon/Campbell Twp., SQUAW CREEK — Peabody Coal Co. Rd. Bridge (Booneville Quad.: T5S, R8W, S6)
40	Gibson Co., Barton Twp., BIG CREEK — W. 900 Rd. Bridge (Elberfeld Quad.: T3S, R9W, S33/34)
41	Warrick Co., Greer Twp., BIG CREEK — Highway 68 Bridge (Lynnville Quad.: T4S, R9W, S2/11)
42	Warrick Co., Hart Twp., BIG CREEK — Highway 61 Bridge (Lynnville Quad.: T4S, R8W, S15)
43	Warrick Co., Greer Twp., PLUM BRANCH — W. 675 Rd. Bridge (Lynnville Quad.: T4S, R9W, S13)
44	Warrick Co., Hart Twp., UNNAMED TRIB. OF BIG CREEK — Highway 68 Bridge (Lynnville Quad.: T4S, R8W, S4/9)
45	Warrick Co., Hart Twp., BIG CREEK — N. 1100 Rd. Bridge (Lynnville Quad.: T4S, R8W, S1/12)
46	Gibson Co., Barton Twp., SMITH FORK — W. 950 Rd. Bridge (Elberfeld Quad.: T3S, R9W, S21)
47	Gibson Co., Barton Twp., SMITH FORK — W. 800 Rd. Bridge (Elberfeld Quad.: T3S, R9W, S22/23)
48	Gibson Co., Barton Twp., SMITH FORK — W. 650 Rd. Bridge (Lynnville Quad.: T3S, R9W, S24)
49	Gibson Co., Barton Twp., SMITH FORK — N. 1400 Rd. Bridge (Lynnville Quad.: T3S, R8W, S20/29)
50	Gibson Co., Barton Twp., HALFMOON CREEK — Highway 68 Bridge (Francisco Quad.: T3S, R9W, S15)
51	Gibson Co., Barton Twp., DONAHUE CREEK — Highway 168 Bridge (Francisco Quad.: T3S, R9W, S14)
52	Gibson Co., Union Twp., SNAKE RUN — Highway 168 Bridge (Francisco Quad.: T3S, R10W, S14)
53	Gibson Co., Center/Union Twp., SAND CREEK — N. 1800 Rd. Bridge (Francisco Quad.: T2S/T3S, R10W, S2/35)
54	Gibson Co., Center Twp., MUDDY FORK DITCH — N. 1900 Rd. Bridge (Francisco Quad.: T2S, R10W, S25/36)
55	Gibson Co., Center Twp., SAND CREEK — N. 1900 Rd. Bridge (Francisco Quad.: T2S, R10W, S26/35)
56	Gibson Co., Union Twp., CLEAR FORK DITCH — N. 1800 Rd. Bridge (Princeton Quad.: T2S/T3S, R10W, S3/34)
57	Gibson Co., Patoka Twp., CLEAR FORK DITCH — N. 1900 Rd. Bridge (Princeton Quad.: T2S, R10W, S29)
58	Gibson Co., Union Twp., WEST FORK OF PIGEON CREEK — W. 1550 Rd. Bridge (Haubstadt Quad.: T3S, R10W, S21)
59	Gibson Co., Union Twp., WEST FORK OF PIGEON CREEK — Coal Mine Rd. Bridge (Haubstadt Quad.: T3S, R11W, S24)
60	Gibson Co., Union Twp., MCGARY DITCH — W. 1975 Rd. Bridge (Princeton Quad.: T3S, R11W, S14)
61	Gibson Co., Union Twp., HURRICANE CREEK DITCH — N. 1325 Rd. Bridge (Haubstadt Quad.: T3S, R10W, S29)
62	Gibson Co., Union Twp., HURRICANE CREEK DITCH — Highway 68 Bridge (Haubstadt Quad.: T4S, R10W, S4)
63	Gibson Co., Johnson Twp., UNNAMED TRIB. OF HURRICANE CREEK DITCH — Highway 68 Bridge (Haubstadt Quad.: T4S, R10W, S4)

TABLE 2. Comparison of young and adult fishes in Pigeon Creek drainage. Results are presented as an average followed by the standard error of the mean. Numbers in parentheses depict number of collecting stations.

	Young	Adult	Total
Pigeon Creek (15)	12.7 ± 4.4	44.0 ± 7.7	56.7 ± 8.1
Tributaries (48)	41.2 ± 9.0	81.8 ± 9.0[1]	123.0 ± 11.2[1]

[1] t-test, $p < .05$

black crappie showed a similar main stream preference, but were found in the tributaries too. In contrast, the grass pickerel, stoneroller, creek chub, creek chubsucker, and longear sunfish were found exclusively in the tributaries. The creek chub was especially common in the drainage and collected in 61.9% of the collections. Other fishes residing primarily in the tributaries were the silverjaw minnow, golden shiner, suckermouth minnow, bluntnose minnow, fathead minnow, black bullhead (young), yellow bullhead (young), pirate perch, pumpkinseed, spotted bass, and slough darter. The mosquitofish displayed a spotty distribution with the majority of collections in the lower reaches of the drainage. Carp and channel catfish demonstrated a similarly spotty distribution, but they were not restricted to any particular region. The redfin shiner preferred the headwaters of Pigeon Creek, while the blackstripe topminnow, green sunfish, and bluegill were distributed throughout the drainage. The latter three species were collected in 79.4%, 74.6%, and 58.7% of the 63 sites sampled respectively. Bluegill were especially concentrated in Little Pigeon Creek. Eight species were collected at but one location in Pigeon Creek. These incidental species were the shortnose gar, quillback, white sucker, smallmouth buffalo, black buffalo, white bass, orangespotted sunfish, and freshwater drum.

The most abundant fishes in the drainage were the creek chub, redfin shiner, blackstripe topminnow, silverjaw minnow, fathead minnow, bluntnose minnow, green sunfish, and bluegill respectively. These eight species comprised 80.4% of the collection, while the remaining 31 species made up 19.6%. The six major families represented in the drainage were the minnow (66.0%), sunfish (18.5%), killifish (9.7%), catfish (3.8%), livebearer (2.0%), and herring (1.5%) families. These families made up 99.5% of the total catch. Twelve species from 8 families accounted for the remaining 0.5%. The sucker family was poorly represented.

In this summer study, the blackstripe topminnow outnumbered mosquitofish by a 5 to 1 ratio. The blackstripe topminnow was found less often with the mosquitofish in the upper region (Station 11 and above) than in the lower region of the drainage (2×2 Chi Square = 9.6; df = 1; $p < .005$).

Species diversity within the drainage ranged from 0 to 3.2 with an average of 2.0 ± 0.7. Stations 16, 39, and 41 had particularly low species diversity indexes (0.5 or less). A fish kill consisting of grass pickerel, bluntnose minnow, creek chub, black bullhead, channel catfish, bluegill, and longear sunfish was found at Station 16. These fishes were found lodged between rocks and partially decomposed. The only living fish observed at this station was the blackstripe topminnow.

Discussion

Pigeon Creek is a base to low-gradient stream. Even though it is the largest drainage in southwestern Indiana (4), it has received little scientific attention. Historically, it's been considered by most residents as polluted, and fish kills, most of which go unreported, are common occurrences. It is classified as a legal drain which makes dredging an acceptable method of channelizing the stream. Stream channelization increases soil erosion, turbidity (with siltation), water temperature, risks to public health, and degradation to habitat and water quality. These factors along with sewage, agricultural, mine acid, and landfill run-off depict Pigeon Creek as a drainage in need of investigation and protection.

In this study, young comprised 31% of the total catch. They were represented in 24 of the 39 species (61.5%) collected in the drainage. This high frequency depicts Pigeon Creek as a valuable breeding tributary of the Ohio River, some species of which are gamefish. The gamefish in the drainage are for the most part within but two families, the catfish and sunfish families. Seventy-nine percent of the catfish collected were young, while 46.8% of the sunfish were young. The black bullhead was the most abundant catfish, while the green sunfish was the most abundant centrarchid. Both of these species are tolerant of turbidity (13).

The tributaries contained a higher number of fishes (both young and adult) than Pigeon Creek. This intradrainage difference may be attributed to the collecting practices employed or habitat differences. The latter is suspected for Pigeon Creek displayed more impermanent bottoms of deep calcitic and organic mud than its tributaries. Due to the greater flow of the mainstream, these sediments are mixed and compounded with erosion of its open banks generates a higher suspended load, more turbid conditions, and thus, more siltation. Siltation was especially notable south of Elberfeld (Station 12) to Millersburg (Station 10). This region exhibited a palustrine, not riverine, habitat. The waters were choked with emergent and floating vegetation. Algal blooms were common here as well as throughout Pigeon Creek.

Siltation as a negative influence is indicated by a comparison of the results of this study with a previous investigation in Pigeon Creek in 1942 (2). The 1942 investigation demonstrated 35 species of fish from 10 families, of which 12 species were not collected in the present study. Thirty-four percent of the fish in Pigeon Creek in 1942 no longer inhabit the drainage. Seven of these twelve (bigeye chub, mimic shiner, pugnose shiner, steelcolor shiner, bluntnose darter, johnny darter, spotted sucker) are adversely affected by siltation (6,9,12); 3 species (bullhead minnow, brown bullhead, and blackside darter) prefer clear water (9,12,13); and 1 species (swamp darter) is out of its range (1,6,12). The last species, the cypress minnow, was collected in only four stations in southwestern Indiana (2) and little is known of its sensitivity or tolerance to siltation. It is commonly found with the silvery minnow (9) which is sensitive to siltation (1). In 1942, 4 darters were collected. Only one darter was found in this study, the slough darter. The slough darter tolerates murky water and silt-bedded pools, but it favors areas with aquatic vegetation (6). The reduction in darters since 1942 suggests a decrease in riffles and silting of the stream. Suckers were not well represented in this study for the same reason. Nevertheless, 23 of the 35 (66%) fishes found in 1942 still occur in Pigeon Creek drainage today. They are the gizzard shad, quillback, creek chubsucker, creek chub, golden shiner, emerald shiner, redfin shiner, carp, suckermouth minnow, bluntnose minnow, mississippi silvery minnow, black bullhead, yellow bullhead, blackstripe topminnow, grass pickerel, pirate perch, green sunfish, warmouth, longear sunfish, bluegill, white crappie, black crappie, and freshwater drum.

Since 1942 there has been an increase in turbidity tolerant fishes, including bluntnose minnow, redfin shiner, black bullhead, and green sunfish. These 4 species comprised 30.6% of the total catch. In addition, 16 new species contributed 41% of the 1986 catch. This difference was expected since we concentrated our efforts throughout the drainage, while in 1942 only 3 stations were sampled. Three of these 16 new species (black buffalo, smallmouth buffalo, white bass) are Ohio River fishes (8) and were collected only at the mouth of Pigeon Creek. The mouth was not sampled in 1942. Four new species were found in the tributaries. They were the silverjaw minnow, stoneroller, fathead minnow, and spotted bass. Likewise, these tributaries were not sampled in 1942. Seven new and incidental species collected in this study were the bowfin, shortnose gar, white sucker, flier, pumpkinseed, orangespotted sunfish, and slough darter. They would not be expected in the 1942 study due to their low frequencies in the drainage. However, two species occurred in higher numbers in the drainage. They were the channel catfish and mosquitofish. The channel catfish was sampled at the mouth of Pigeon Creek in 1888 (5). It is possible that the channel catfish was missed in 1942 since it made up but 0.3% of the total catch in 1986. However, mosquitofish were in sufficient numbers and in the area of the three stations sampled in 1942. This lack of mosquitofish in 1942 suggests a habitat change and/or recent colonization today.

The blackstripe topminnow and mosquitofish are ecological equivalents. The blackstripe topminnow was distributed virtually throughout the drainage and outnumbered the mosquitofish by a ratio of 5 to 1. Even though the blackstripe topminnow was clearly the most dominant species of the two in the drainage, it was found more often with the mosquitofish in the lower than upper regions. A recent colonization by the mosquitofish caused by a change in habitat in Pigeon Creek is suggested. The mosquitofish prefers slower, deeper, more vegetated waters than the blackstripe topminnow. Follow-up studies on their distributions and frequencies in the drainage is warranted.

Even though the majority of Pigeon Creek drainage is murky with deep mud bottoms, Smith Fork displayed clear waters with a sand and gravel substrate. This tributary contained populations of longear sunfish, spotted bass, bluegill, silverjaw minnow, and creek chub. Clearer streams such as Smith Fork were probably more abundant in the 1940s than now and thus promoted more siltation sensitive fishes (2). Siltation appears to be the most influential factor affecting populations and community structure of fishes in Pigeon Creek today.

Acknowledgments

Special thanks are extended to the following persons for their assistance and support during this study: James H. Bandoli, Marie E. Cervone, Melvin W. Denner, Chris E. Freiburger, Paul A. Glander, and Michael V. Thomas. To the parents of the authors, we thank you for your love and support.

Literature Cited

1. Clay, W.M. 1975. The Fishes of Kentucky. Kentucky Dept. of Fish and Wildlife Resources, Frankfort, Kentucky. 416 pp.
2. Gerking, S.D. 1945. The distribution of the fishes of Indiana. Investigations of Indiana Lakes and Streams, 3(1):1-137.
3. Hair, J.D. 1980. Measurement of Ecological Diversity (Chap. 16) in Wildlife Management Techniques Manual (4th ed.), edited by Sanford D. Schemnitz. The Wildlife Society, Inc., Washington, D.C. 269-275 pp.
4. Hoggatt, R.E. 1975. Drainage Areas of Indiana Streams. U.S. Dept. of the Interior, Geol. Surv. Water Resources Div. 231 pp.
5. Jordan, D.S. 1890. Report of explorations made during the summer and autumn of 1888, in the Allegheny region of Virginia, North Carolina, and Tennessee, and in western Indiana, with an account of the fishes found in each of the river basins of those regions. Bull. U.S. Fish Comm., 8:97-173.
6. Kuehne, R.A. and R.W. Barbour. 1983. The American Darters. The University Press of Kentucky, Lexington, Kentucky. 177 pp.
7. Nelson, J.S. and S.D. Gerking. 1968. Annotated Key to the Fishes of Indiana. Dept. of Zoology, Indiana Univ., Bloomington, Indiana. 84 pp.
8. Geo-Marine, Inc. 1984. Ohio River Ecological Research Program—Adult and Juvenile Fish, Ichthyoplankton, and Macroinvertebrate Studies. Plano, Texas. 504 pp.
9. Pflieger, W.L. 1975. The Fishes of Missouri. Missouri Dept. of Conservation. 343 pp.
10. Poole, R.W. 1974. An Introduction to Quantitative Ecology. McGraw-Hill, New York. 532 pp.
11. Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. Amer. Fisheries Society, Spec. Pub. #12, 174 pp.
12. Smith, P.W. 1979. The Fishes of Illinois. Univ. of Illinois Press, Urbana, Illinois. 314 pp.
13. Trautman, M.B. 1981. The Fishes of Ohio. Ohio State Univ. Press, Columbus, Ohio. 782 pp.
14. Wayne, W.S. 1956. Thickness of drift and bedrock physiography of Indiana north of the Wisconsin glacial boundary. Indiana Dept. Conserv. Geol. Surv. Rept. of Progress, No. 7. 70 pp.

The Relation between Ovum Variability and Larval Growth in *Ambystoma tigrinum*, Amphibia: Urodela

DAVID M. SEVER, STEPHANIE A. KRAMER AND SUSAN DUFF
Department of Biology
Saint Mary's College
Notre Dame, Indiana 46556

Introduction

In three species of ambystomatid salamanders, including *A. tigrinum*, Kaplan (4) reported that larger eggs result in hatchlings that reach the feeding stage earlier than hatchlings from smaller eggs. Subsequently, the absolute difference in size between the larvae resulting from large eggs and those from smaller eggs becomes amplified with time (4). Larger larvae may be able to metamorphose more quickly, and this might be adaptive in an ephemeral pond environment. Thus, the size of eggs that a female produces may have implications for her reproducive fitness (4, 6, 11). Walls and Altig (11), however, found that the relation between egg size, hatchling length and larval growth held for some species of *Ambystoma* but not for others. Also, although larger eggs produce larger larvae that reach the feeding stage earlier than smaller larvae in the newt *Taricha torosa*, Kaplan (5) reported that larvae from large eggs metamorphose in less time and at a larger size than those from small eggs only in a food unlimited situation. In a food limited situation, larvae from larger eggs still were larger at metamorphosis but the time to metamorphosis was greater than that of larvae from smaller eggs. Finally, Nussbaum (7) noted that the ranges of egg size across populations of ambystomatids are small and suggested that factors other than egg size, both genetic and ecological, may be more important in determining the length of the embryonic period.

We studied a population of *A. tigrinum* that breeds in a temporary pond in northern Indiana. Previous studies on this population have shown that hatching of eggs is nearly synchronous, but great differences in subsequent growth occur among the larvae (6, 9). Our purpose was to see if the range of larval size could be explained by concordant variation in ovum size.

Materials and Methods

Snout-vent length (svl) was measured from tip of the snout to posterior end of the vent with calipers to the nearest 0.5 mm in living specimens and nearest 0.1 mm in preserved specimens. Statistical tests followed Sokal and Rohlf (10).

The study pond was located in St. Joseph County, Indiana. This locale and its breeding population of *Ambystoma tigrinum* were described in detail by Sever and Dineen (9). Briefly, the pond is formed by melting snow and rainfall in winter, and at maximum size, the pond is 0.25 ha and 90 cm deep. The pond dries completely each summer. *Ambystoma tigrinum* is the only salamander using the pond, but *Bufo americanus* breeds in the pond and two other anurans, *Pseudacris triseriata* and *Hyla versicolor* probably do.

In 1985, five females 9.7-12.4 cm svl ($\bar{x}$ = 11.0 mm, S.D. = 1.06) were collected from the study pond following mating but prior to oviposition as determined by presence of a spermatophore cap in the cloacal orifice. These females oviposited in the laboratory, and clutch size was 344-543 ($\bar{x}$ = 450.8, S.D. = 88.2). Following preservation of the eggs in 10% formaldehyde, ova diamters were measured to the nearest 0.01 mm using an ocular micrometer in a dissecting microscope. Mean egg diameters were 1.58-1.68 mm, and a one-way analysis of variance showed significant differences ($p < 0.5$, F = 331.8) in mean ovum diameter among females. From this preliminary study, we determined that measuring 25 eggs from a single female was sufficient to be within 0.03 mm of the true mean ovum diameter of the entire clutch at a 95% confidence level.

On 12-14 March, 1986, 10 gravid female *A. tigrinum* 9.5-11.5 cm svl ($\bar{x}$ = 10.5, SD = 0.77) were collected from the study pond. Some females had spermatophore caps visible in the cloacal orifice, but others did not, and these latter individuals may have oviposited some eggs in the pond prior to their collection. The females were placed in tanks containing twigs for attachment of egg masses. Oviposition occurred within 2 days of collection for all females. Clutches contained 228-815 eggs ($\bar{x}$ = 448.8, S.D. = 197.2). From each clutch, 25 eggs were randomly selected and measured to the nearest 0.02 mm.

On 17 March, the clutches were taken to the pond and placed in containers that were distributed evenly around the pond and submerged in 60 cm of water. The containers were plastic buckets 36 cm in length × 29 cm in widest diameter with openings ∿20 cm in diameter cut in the bottom and in the lid. Over the openings wire mesh was stapled. The mesh size, ∿1.5 mm square, was large enough to allow passage of small invertebrate prey items (9) but small enough to prevent passage of hatchling salamander larvae.

The larvae in the 10 buckets hatched by 11 April. On that date, the number of larvae that had survived to hatching in each clutch was noted. Larvae were anesthetized in an ether solution (1:9 water), and 25 larvae were randomly chosen from those in each bucket and measured. After recovery from anesthesia, the larvae were returned to their buckets. No immediate mortality from the anesthetic was noted.

All living larvae in each bucket subsequently were measured on 25 April and 9 May. Measurement of larvae was discontinued after 9 May due to high mortality, including complete mortality in two buckets.

In addition, a minimum of 25 free swimming larvae were collected from the pond on 11 April, 25 April, 9 May and at 14-18 day intervals until the pond dried completely on 22 August. These larvae were measured after preservation in 10% formaldehyde.

Results

Mortality of Eggs and Larvae

Mortality data for the eggs and larvae in each container are given in Table 1. Overall, mortality from oviposition to hatching was 63.5-98.1% ($\bar{x}$ = 87.3%, SD = 9.93). Cumulative percent mortality between oviposition and 25 April was 90.7-99.6% ($\bar{x}$ = 95.0%,

TABLE 1. Cumulative percent mortality (CPM) among eggs and larvae reared in containers in the study pond.

Bucket	17 March	11 April		25 April		9 May	
	N	N	CPM	N	CPM	N	CPM
1	433	51	88.2	23	94.7	5	98.8
2	815	157	80.7	76	90.7	9	98.9
3	265	36	86.4	19	92.8	14	94.7
4	604	82	86.4	44	92.7	14	97.7
5	695	44	93.7	28	96.0	9	98.7
6	318	43	86.5	21	93.4	11	96.6
7	359	131	63.5	28	92.2	5	96.2
8	297	23	92.3	3	99.0	1	99.7
9	464	9	98.1	4	99.1	0	100
10	228	7	96.9	1	99.6	0	100

SD = 3.23) and between oviposition and 9 May was 94.7-100% ($\bar{x}$ = 98.1, SD = 1.79). Following hatching, mortality may have been influenced by cannibalism. One larvae in a container was observed engulfing another on 25 April.

Variation in Size of Ova and Larvae

Lengths of the larvae in the buckets were compared with those of free-swimming larvae collected on the same dates that the caged larvae were measured. Since the free-swimming larvae were undoubtedly of multiple parentage, a group mean for them was compared with a group mean for all the larvae measured from the buckets on a given date. No significant difference ($p > 0.05$) occurred between mean larval length for the caged and free-swimming larvae on 11 April, but differences between the means were significant ($p < 0.05$) for larvae from 25 April and 9 May (Table 2). The mean for the free-swimming larvae ws larger than that for the larvae in buckets on 25 April and 9 May.

Table 2. Differences in snout-vent length between larvae in the buckets (Caged) and free-swimming larvae (Free). The F ratio for the 11 April larvae was not significant ($p > 0.05$) while those for 15 April and 9 May were significant ($p < 0.05$). Measurements are in mm.

Date	Caged				Free				F
	N	Range	Mean	SD	N	Range	Mean	SD	
11 April	222	5.0- 9.0	7.59	0.80	25	6.0- 9.0	7.72	1.02	0.55
25 April	248	7.0-15.0	10.69	1.45	23	9.0-14.0	11.56	1.47	7.72
9 May	68	11.5-32.0	18.77	4.01	23	19.0-32.0	24.24	3.81	32.71

The comparisons in Table 2 were made between larvae from the buckets measured alive while anesthetized and free-swimming larvae measured after preservation in 10% formaldehyde. To check the effects of preservation on the measurements, the free-swimming larvae collected 9 May were measured alive while anesthetized and remeasured after preservation. Measurements of the living specimens were 19-34 mm svl ($\bar{x}$ = 25.5 mm, SD = 4.07) as opposed to 19-32 mm svl ($\bar{x}$ = 24.2 mm, SD = 3.81) for preserved larvae, not a significant difference at $p < 0.05$ (F = 1.26).

One-way analyses of variance were conducted to test the hypotheses that no variation existed among females in the size of their eggs at oviposition or their larvae on any of the dates when the larvae from the buckets were measured. Because complete mortality occurred in two buckets by 9 May, only the eight buckets that still contained larvae on 9 May were used in the analyses. The null hypotheses were rejected. Variance was significant at $p < 0.05$ for ovum size (F = 15.70), 11 April larval lengths (F = 7.50), 25 April larval lengths (F = 3.56) and 9 May larval lengths (F = 2.79).

Hochberg's GT-2 *a posteriori* test was used to see how the means analyzed contributed to rejection of the null hypotheses. This test found subsets of means within which differences were not significant at $p > 0.05$. Mean egg sizes were 2.09-2.32 mm, and five overlapping subsets of means were found. Three subsets of means were found for 11 April larval lengths (6.88-7.30 mm, 7.30-7.92 mm, and 7.64-8.00 mm). Significant variances on 25 April and 9 May were due to differences between the lowest and the highest means. Mean larval lengths on 25 April were 9.76-12.83 mm with subsets of 9.76-11.02 mm and 10.55-12.83 mm. For 9 May, the range was 14.90-23.00 mm with subsets of 14.90-20.50 mm and 16.68-23.00 mm.

Thus, larvae from seven of the buckets on 25 April and 9 May did not differ in mean svl length from one another. The buckets containing the largest and smallest larvae were not the same on these two dates. Bucket 7 actually changed from the container having the smallest larvae on 25 April to containing the largest larvae on 9 May.

The maximum range in larval size in the buckets after hatching was 2.5 mm (6.5-9.0 mm) and the minimum was 1.5 mm (6.0-7.5 mm). On 25 April, the maximum range in larval size was 7.0 mm (8.0-15.0 mm), and the minimum was 4.0 mm (9.0-13.0 mm) excluding bucket 8, in which just three larvae (12.0-13.5 mm) remained. In the 5 buckets with N $\geq$ 9 larvae on 9 May, the maximum range of larval sizes was 17.0 mm (15.0-32.0 mm), and the minimum range was 6.5 mm (13.5-20.0 mm).

Variation in larval size among free-swimming larvae also was small at hatching but increased markedly by 9 May (Figure 1). Thereafter, variation in svl of free-swimming larvae remained high with the greatest range, 26-58 mm, occurring on 11 July.

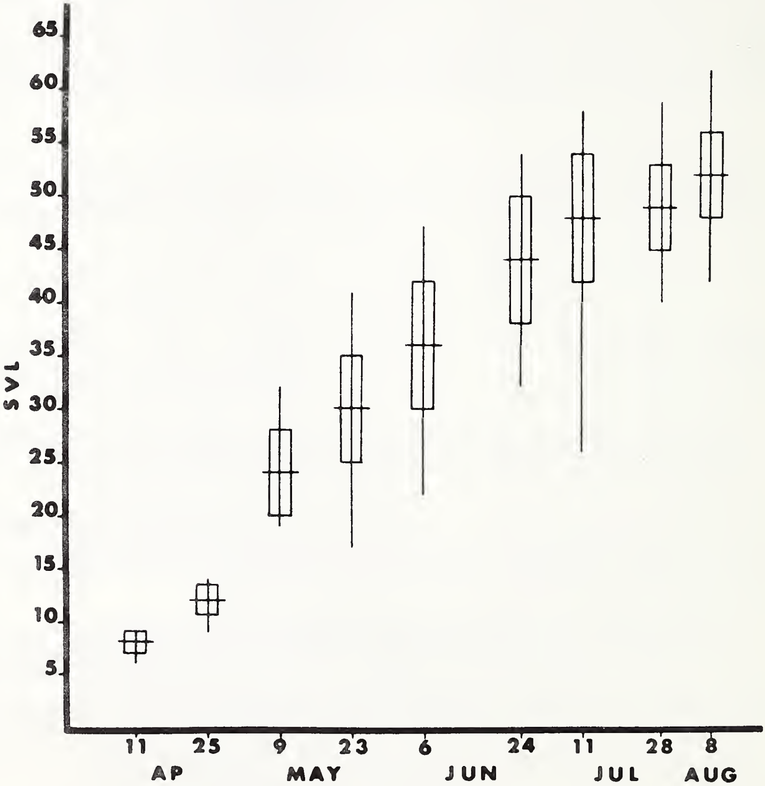


FIGURE 1. Growth of free-swimming larvae collected during the summer of 1986. The vertical line is the range in snout-vent length (svl); the horizontal line is the mean; and the box above and below the mean is one standard deviation.

Concordance of Ovum Size and Larval Growth

Kendall's coefiicient of concordance was used to test the null hypothesis that no relationship exists among the rank order of mean egg diameters and larval sizes in the sequential sampling data from the eight buckets used in the analyses of variance. The hypothesis was accepted as concordance of means was not significant at $p > 0.05$ ($W = 0.24$, $\chi^2 = 6.74$). Thus, the variation in larval size could not be attributed to a consistent pattern of variation in egg or larval size observed in the samples.

Discussion

Survivorship and Growth

Couture and Sever (2) followed mortality in clutches of *A. tigrinum* in natural situations in the study pond and reported 74.3% cummulative mortality from cleavage to neurla. This is less than the mortality we found in the buckets between oviposition and hatching (87.3%), but our results and those of Couture and Sever cannot be compared statistically.

Likewise, the significance of the mortality we found in the buckets through 9 May is unclear, as no comparable data on natural mortality during this period are available for free-swimming larvae in the study pond. Anderson *et al.* (1), in a population of *A. tigrinum* in New Jersey, found that 3.3% of the eggs deposited survived to metamorphosis. The relation of larval density to survivorship and growth in natural and artificial situations is complex (8, 12). Generally, higher survivorship to metamorphosis has been noted in amphibians in field enclosures versus natural habitats (8).

Growth of larvae may be related to density, with larvae growing slower under crowded conditions (8). In this regard our data indicate that at hatching larvae in the buckets were not different in mean svl from free-swimming larvae in the study pond, but that on our last two sample dates, free-swimming larvae were significantly larger than those in the buckets. Either we were not efficiently sampling smaller free-swimming larvae on 25 April and 9 May, or else the growth of free-swimming larvae was greater than that of larvae in the buckets. In the latter case, the presumed higher density of larvae in the buckets than in the pond may have affected their growth (8, 12).

Ovum Size and Larval Growth

Our results for the larvae in the buckets may not reflect the situation under natural conditions due to the influence of larval density and prey availability on growth of larvae (5, 8, 12). In particular, Kaplan's (5) report that larvae of *T. torosa* from large eggs grow faster than those of larvae from small eggs only in food unlimited situations may be relevant.

We do not know, however, whether the density of larval *A. tigrinum* and prey items in our enclosures was different from that for free-swimming larvae, or if density factors affect the growth of larval *A. tigrinum* like they influence growth of larval *T. torosa.* Indeed, the density of larval *A. tigrinum* in the enclosures may actually increase the growth rate of larger larvae since the larger larvae may find the smaller ones to be an abundant and concentrated source of prey. The cannibalistic nature of larval *A. tigrinum* is well-known (3, 6), and we observed cannibalism among larvae in the buckets during the study. In contrast, Sever and Dineen (9) did not find cannibalism occurring among free-swimming larvae in the study pond based upon an examination of stomach contents.

In bucket 7 on 25 April, 28 larvae occurred, and the mean for larvae in this bucket was the smallest of that for the eight buckets on this date. On 9 May, however, only 5 larvae were present in bucket 7, but the mean for these larvae was the largest of that for the buckets. Could cannibalism have been involved? If so, density of larvae increased the growth of those larvae large enough to engulf their siblings. Our laboratory and field observations indicate that the difference in size necessary for cannibalism to occur is small, although this has not been quantified.

Obviously, more work is needed before the dynamics of larval growth of *A. triginum* are elucidated in our study pond. Our reuslts demonstrate that: (1) a difference in mean egg size does occur among female *A. tigrinum*; (2) variability occurs in growth rates among the offspring of individual females; and (3) the variability in larval growth cannot be explained simply in terms of ovum size. Thus, although larval growth may be involved, the selective pressure for the number and size of eggs produced by female *A. tigrinum* in the study pond may include other factors as well.

Acknowledgments

We thank Angela Gonzalez for the preliminary work she did in 1985 on ovum variability in tiger salamanders. We thank R. Jensen for his advice on statistical procedures. This research was supported by a much appreciated grant from the Indiana Academy of Science.

Literature Cited

1. Anderson, J.D., D.D. Hassinger, and G.H. Dalrymple. 1971. Natural mortality of eggs and larvae of *Ambystoma t. tigrinum*. Ecology 59:1107-1112.
2. Couture, M.R. and D.M. Sever. 1979. Developmental mortality of *Ambystoma tigrinum* (Amphibia: Urodela) in northern Indiana. Proc. Ind. Acad. Sci. 88:173-175.
3. Crump, M.L. 1983. Opportunistic cannibalism by amphibian larvae in temporary aquatic environments. Am. Nat. 121:281-287.
4. Kaplan, R.H. 1980. The implications of ovum size variability for offspring fitness and clutch size within several populations of salamanders (*Ambystoma*). Evolution 34:51-64.
5. Kaplan, R.H. 1985. Maternal influences on offspring development in the California newt. *Taricha torosa*. Copeia 1985:1028-1035.
6. Mould, E.D. and D.M. Sever. 1984. Body size and lipid content of *Ambystoma tigrinum* during larval ontogeny. Herpetologica 40:176-181.
7. Nussbaum, R.A. 1985. The evolution of parental care in salamanders. Misc. Publ. Mus. Zool. Univ. Mich. 169:1-50.
8. Petranka, J.W. and A. Sih. 1986. Environmental instability, competition, and density-dependent growth and survivorshi of a stream-dwelling salamander. Ecology 67:729-736.
9. Sever, D.M. and C.F. Dineen. 1978. Reproductive ecology of the tiger salamander, *Ambystoma tigrinum*, in northern Indiana. Proc. Ind. Acad. Sci. 87:189-203.
10. Sokal, R.R., and F.J. Rohlf. 1981. Biometry. The principles and practice of statistics in biological research, 2nd ed. W.H. Freeman, San Francisco. 859 pp.
11. Walls, S.C. and R. Altig. 1986. Female reproductive biology and larval life history of *Ambystoma* salamanders: a comparison of egg size, hatchling size, and larval growth. Herpetologica 42:334-345.
12. Wilbur, H.M. 1976. Density-dependent aspects of metamorphosis in *Ambystoma* and *Rana sylvatica*. Ecology 57:1289-1296.

The Upland Sandpiper, *Bartramia longicauda*, Breeding Area in South Bend, Indiana

David L. Snyder
Lobund Laboratory
University of Notre Dame
Notre Dame, Indiana 46556

Victor Riemenschneider
Biology Department
Indiana University at South Bend
South Bend, Indiana 46615

Virgil W. Inman
South Bend Audubon Society
52851 Shellbark
South Bend, Indiana 46628

Introduction

The Upland Sandpiper (*Bartramia longicauda*) is a migratory bird which originally bred throughout the grasslands of the United States and Canada. It winters in the southern South American countries of Surinam, Argentina, Uruguay and Brazil (8). Since the turn of the century, declines in their number have been attributed to two factors: hunting pressure in the early 1900's (3) and destruction of native grasslands particularly in the eastern United States (11). Osborne and Peterson (14) reported significant declines in distribution and numbers in Ohio. Upland Sandpipers were common in Indiana 100 years ago (6), but are rare today (13). Tate (17) attributes declines in their eastern range to the maturation and replacement of old field habitats. Continuation of breeding populations in the eastern United States depends on the preservation of adequate breeding habitat.

In Wisconsin (18) and North Dakota (9,11) pastures, hay fields and small grain crop fields are the preferred habitats. The short grass fields of airports are now important habitat for the Upland Sandpiper in eastern states like Indiana where row crops are common (13,14) and tall grass prairies are practically gone. Osborne and Peterson (14) estimate that almost 75 percent of the Upland Sandpipers in Ohio use airports as breeding areas; they describe airports as "critical refuges for this endangered species." Beck (2) reported that from 1921 to 1954 Upland Sandpiper sightings increased at the Lancaster Municipal Airport (in southeastern Pennsylvania). From 1900 to 1921 numbers in the county had fallen from 500 to only 21, but in 1954 the airport held 140 of the 156 birds in the county. In Wisconsin 2 percent of nests are found on airfields (18). Brock (4) reported sighting 7 Upland Sandpipers in the grassy areas adjacent to the Gary Airport in northwestern Indiana on July 26, 1980. The region around South Bend has lost considerable grassland habitat, making the airport a prime site for breeding. Since native and non-native grassland habitats are disappearing in many mid-western states, properly managed airports may provide local areas for stable breeding populations of Upland Sandpipers.

The Upland Sandpiper is on the Indiana state endangered species list and since 1975 has been on the Blue List of *American Birds,* National Audubon Society's list of birds of concern due to declining populations (17). In Indiana, two agencies of the Department of Natural Resources, the Nongame Wildlife and the Heritage Programs, have identified only five nesting populations in Indiana. The largest and best documented area is located in northern Indiana on the property of the Michiana Regional Airport (MRA) and adjacent industrial park (Personal communication with Brian Abrell, Indiana Division of Natural Resources, 1986). Parts of this breeding area are included in planned expansion of the industrial complex and airport in 1987.

In order to maintain this breeding area, the Michiana Regional Airport Authority (MRAA) has agreed to preserve part of their property through the Indiana Natural Areas Registry Program. Now called Bendix Meadow, this area of approximately 35 hectares was once a county landfill and is not part of any future airport expansion. The South Bend Audubon Society (SBAS) has entered into an agreement with the MRAA to manage Bendix Meadow as an Upland Sandpiper breeding area. From April to July of 1986 the SBAS examined the Upland Sandpiper's use of Bendix Meadow, the MRA and the industrial park in order to design a management plan for maintenance of the breeding area.

Methods

Records from the SBAS were examined for Upland Sandpiper sightings prior to 1980. Observations made during 1983, 1984 and 1985 were used to estimate timing, numbers and habitat use prior to 1986. USDA aerial photographs from 1951 and 1980 were used to estimate land use changes in the MRA and the surrounding area and the size of each site in the breeding area. Vegetative cover in the tall grass sites was identified in 1986 according to species, and percentage cover was estimated for each species.

In 1986, preliminary attempts were made to alter Bendix Meadow to increase Upland Sandpiper use. These birds habitually perch on posts and often use telephone poles and light poles within the study area. Therefore, in March, 20 posts were set at six evenly-spaced sites in two parallel lines, approximately 600 meters long and 100 meters apart. At most sites a single 10 cm by 10 cm wooden post stands 1.2 m above the ground. However, at three sites three or four posts were set at five meter intervals.

Observations began in April 1986 to record the first arrivals. Beginning on May 29, a census route covering the entire breeding area was traversed by car five evenings a week. One night a week the perimeter of the Bendix Meadow site was walked by a single observer. Sightings were recorded on a map together with time and behavior. Behavior was generally divided into foraging, perching, flying and special behavior patterns. Excited flying and whistling around an observer was used as an indicator of a nesting site (5). Observations continued until July 16, when no birds could be found. In addition, sightings of other tall grass prairie birds were recorded.

Results

The current breeding area (see Figure 1) covers 319 hectares: 200 ha in the airport (areas 2 and 3), 84 ha in the industrial park (area 1) and 35 ha in Bendix Meadow. The airport area comprises 152 ha of short, frequently cut grass surrounding the airfield (area 3); a prime breeding area of 48 ha of tall grass fields (not cut during the summer) is within 50 yards of the airfield (area 2). Area 2 will be destroyed by airport expansion in 1987. The industrial park area is about evenly divided between short grass lawns and a tall grass area that borders the railroad. Approximately 20 ha of the industrial park were planted in oats. The tall grass sites were composed mostly of meadow fescue, alfalfa, orchard grass and smooth brome (Table 1).

Table 2 gives the visual land use changes from 1951 to 1980 in the 981 ha area that includes the MRA and adjacent areas. The most obvious changes were the urbanization southeast of the airport, the development of the industrial park northeast of the airport, the decrease in cropland and the increase in open water areas. The growth in commercial/industrial land and expansion of the airport increased the mowed grass areas. Although the percentage of residential area remained the same, housing density increased due to the loss of farmsteads and the increase in urban development. Most of the abandoned farmland is now dominated by grass and other old field herbaceous species.

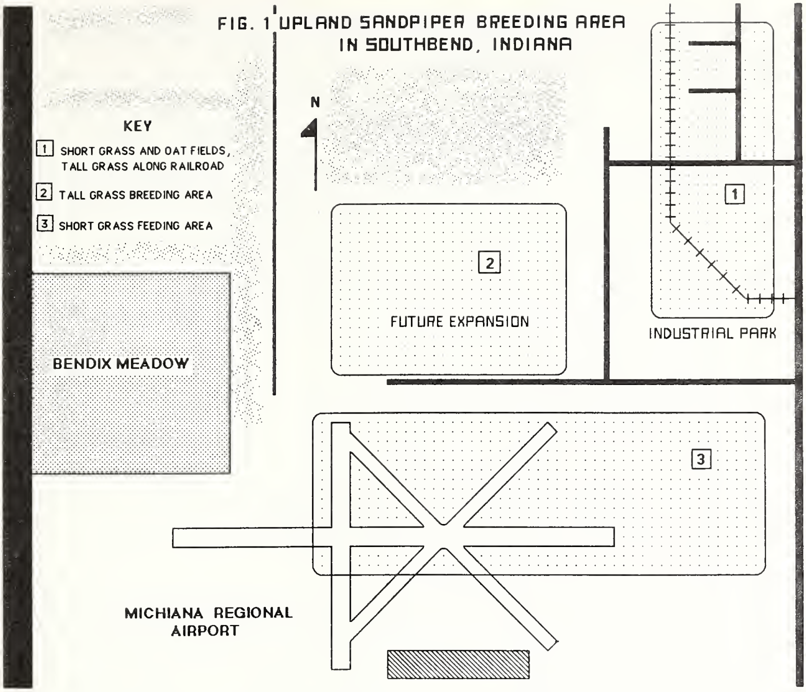


FIG. 1 UPLAND SANDPIPER BREEDING AREA
IN SOUTHBEND, INDIANA
KEY
1 SHORT GRASS AND OAT FIELDS, TALL GRASS ALONG RAILROAD
2 TALL GRASS BREEDING AREA
3 SHORT GRASS FEEDING AREA
N
BENDIX MEADOW
2
FUTURE EXPANSION
1
INDUSTRIAL PARK
3
MICHIANA REGIONAL AIRPORT

Figure 1. Upland Sandpiper Breeding Area in South Bend, Indiana

Table 1. Flora of Bendix Meadow at Michigan Regional Airport

Estimated		
Species	Common Name	Cover
DOMINANT SPECIES:		
1. *Festuca elatior* L.	Meadow Fescue	60%
2. *Medicago sativa* L.	Alfalfa	30
3. *Dactylis glomerata* L.	Orchard Grass	20
4. *Bromus inermis* Leyss.	Smooth Brome	10
ASSOCIATED SPECIES*:		
5. *Aster* (*ericoides* L.)	Heath Aster	5
6. *Phleum pratense* L.	Timothy	5
7. *Agropyron* (*trachycaulum* (Link) Malte)	Wheat Grass	2
8. *Trifolium pratense* L.	Red Clover	2

* There were 22 other associated species with an estimated cover of less than one percent. Species and common names are from F. Swink and G. Wilhelm (1979). Species epithets in parentheses are uncertain.

SBAS records show that the airport supported a small number of Upland Sandpipers in 1972. Prior to 1972 some birds were seen in farm fields outside South Bend, but today these farms are gone or planted in corn. Regular sightings in 1983, 1984 and 1985 show that the first Upland Sandpipers arrive at the airport in the middle of April,

TABLE 2. Land Use in the Michiana Regional Airport and Surrounding Area, 1951 and 1980, from USDA Aerial Photographs.

Land Use	1951 Hectares	1951 %	1980 Hectares	1980 %
Residential*		7		7
Rural	64		28	
Urban	0		38	
Commercial/Industrial	0	0	100	10
Transportation				
Roads/Runways	42	4	61	6
Cropland/Hay Fields	500	51	211	22
Woodlands/Orchard/ Pine Plantations*	21	2	9	1
Woody Old Fields/Gravel Pits*	176	18	175	18
Grassland Old Fields/(mown and unmown)	178	18	344	35
Ponds/Sewage Lagoons	0	0	10	1
Totals	981	100	976	100
Fence Rows (meters)	18,656		14,292	

The scales of the aerial photographs were 1:7920 for 1951 and 1:12000 for 1980. A 10 cm by 10 cm modified acreage grid with 32 rows and columns of dots was used to determine land area.
* Areas not used by Upland Sandpipers.

courtship and breeding are in early May, young are seen in early June and all birds have left by late July. Peak numbers varied from year to year. They were: in 1983, 21 adults and 12 young on July 3; in 1984, 10 on June 21; in 1985, 25 adults on June 15.

The first sighting of 1986 was a group of four birds seen in area 3 on April 14. Between May 29 and June 7, the largest daily sighting was 11. On June 7, the first young were observed. Increasing numbers of birds were seen between June 7 and June 23 with a high of 44 birds on June 15. No more than 12 birds were observed from June 24 to July 11 when sightings ended. In late May and early June the majority of sightings were in and near the oat fields of area 1. Sightings in area 1 ended on June 25 when the oats were cut for hay. Sightings in areas 2 and 3 began to increase on June 7. A majority of all sightings were recorded in areas 2 and 3 from June 20 to July 11. On July 5 the only sighting was 12 birds using the airfield. The last sighting (5 birds) was made in the same location on July 11. The tall grass site adjacent to the airfield (area 2) was an active breeding area; the first young were seen at this site. Based on the number of birds exhibiting breeding behavior, there were approximately 15 nests in the study area, a density of 1 nest/21.3 ha. Judging from the maximum number of birds seen on various sites, there were approximately 52 individuals including young in the study area by late June. The Bendix Meadow site was used by only a single breeding pair. The grass on this site was over a meter high by early May and was unsuitable for breeding.

Behavior patterns were divided into three broad classes: foraging, perching and flying. Two distinct calls, an excited distress call given while flying and a melodic but mournful call commonly used while perching, were noted. In area 1, Upland Sandpipers were most often seen foraging in the short grass and oat fields surrounding the buildings of the industrial park or perched on telephone and light poles. A strip of tall grass which was used for nesting bordered the railroad tracks which stretched along the length of area 1. Utility poles along the railroad were a favorite perch. Young were often seen along the tracks while adults perched on the poles. Area 2 had no posts suitable for Upland Sandpiper perches. Observations were limited to birds foraging and moving through the grass or flying. We frequently heard melodic calls from birds hidden in the tall grass, or saw birds using the distress call while flying. The majority of birds in area 3 were seen foraging. Numerous young were seen with the adults in this area. Perching was limited to the short runway lights and a few runway light towers. Melodic calling from perches was common in area 3. Many birds would fly in from other areas, perch on the runway lights and give their distinct calls.

Other species frequently seen in the study area were Eastern Meadowlarks, Bobolinks, Red-winged Blackbirds and Grasshopper Sparrows. Meadowlarks were seen primarily in areas 1, 2, and Bendix Meadow. The Bobolinks and Red-winged Blackbirds were only seen in Bendix Meadow, where the males used the artificial posts in April and May. The Grasshopper Sparrow was fairly common in area 2 and Bendix Meadow. Two species which are now rare in northern Indiana, the Dickcissel and the Henslow's Sparrow, also were found in Bendix Meadow. A breeding pair of Dickcissels were seen from May through June and a pair of nesting Henslow's Sparrows was seen in July.

Discussion

Reports from Wisconsin (18), Illinois (7), North Dakota (11) and South Dakota (10) indicate that Upland Sandpipers prefer pasture and prairie-grassland for nesting. Grazed and burned pasture was more heavily used than ungrazed or unburned areas in the North Dakota study. The South Dakota study suggested that 20 to 40 percent of the current year's plant growth could be removed without restricting nesting. In South Dakota, nests were found in native prairie grasslands associated with four common species: Kentucky bluegrass, native forbs, western wheatgrass and green needlegrass (10). The bluegrass had invaded the native prairie. In North Dakota bluegrass together with quackgrass and smooth bromegrass had also invaded the native prairie used by Upland Sandpipers for nesting (11). Though the grasses of the Bendix Meadow and MRA sites do not correspond to those in North and South Dakota, they do offer similar cover. In Wisconsin the uplands use agricultural land, mostly green pastures and hay and oat fields (18).

Vegetative height is also an important consideration in nest site selection by Upland Sandpipers. Kirsch and Higgins (11) and Kaiser (10), in North Dakota and South Dakota respectively, found no nesting in grass taller than 63.5 cm. Since Bendix Meadow was higher than this critical level by early May, the Upland Sandpipers may have avoided this area for breeding. Buss and Hawkins (5) and Ailes (1) state that short grass areas under 15 cm are preferred for foraging for insects. After hatching, the young are immediately taken to these fields. The short grass lawns of the MRA and industrial park seem to serve this purpose. Nest densities in good quality grassland (both native and non-native) were reported for central Wisconsin as 1/13.1 ha (1); North Dakota 1/16.0 ha (11); and South Dakota, 1/15.6 ha (10). Nesting and total numbers at MRA have changed little during the years 1983 to 1986. With better management of the tall grass areas, especially Bendix Meadow, the nesting density (1/21.3 ha) and total numbers could be increased.

The behavior patterns and calls of the Upland Sandpipers we studied are similar to those reported in Wisconsin by Buss and Hawkins (5) and Ailes (1). Adjacent areas for foraging, nesting and perching were also seen in those studies. The Wisconsin and South Dakota studies mention the use of fence posts and telephone poles but not artificial posts. A study on the Kansas prairies showed that artificial posts would attract Upland Sandpipers as well as numerous other birds (12). Though few uplands were seen using the posts in Bendix Meadow, Red-winged Blackbirds, Bobolinks, Eastern Meadowlarks and Grasshopper Sparrows regularly used them.

In addition to the Upland Sandpiper, the Dickcissel, the Grasshopper Sparrow, and the Henslow's Sparrow are on the Blue List of *American Birds* (17). These birds were common in northern Indiana in early years (6), but today SBAS records show that Dickcissel, Grasshopper Sparrow, and Henslow's Sparrow numbers have declined in recent years. Maintaining the MRA's tall grass habitat will benefit these species.

Airports within the eastern range of the Upland Sandpiper may be the only sites where enough open, high quality grassland exists for breeding. Therefore the study of these sites is important if breeding populations are to be maintained. Management techniques such as grass cutting, post placement and reseeding to native prairie grasses can be examined at Bendix Meadow. Eventually, this portion of airport property may become ideal for prairie bird breeding and help to maintain a stable local breeding population in northern Indiana.

Acknowledgments

This research was supported by grants from the Indiana Academy of Science and the South Bend Audubon Society. Jay Grass made the daily evening observations. We also wish to thank Marcie Inman, Marge Riemenschneider and Arlene Snyder for their assistance. The Michiana Regional Airport Authority deserves recognition for allowing us to conduct this research on their property.

Literature Cited

1. Ailes, I.W. 1976. Ecology of the Upland Sandpiper in central Wisconsin. M.S. Thesis. The University of Wisconsin-Stevens Point. 63 pp.
2. Beck, H.H. 1956. Status of the Upland Plover in Lancaster County, Pennsylvania. Auk 73:202-204.
3. Bent, A.C. 1929. Life histories of North American shorebirds (Part 2). Bull. U.S. Nat. Mus. 146:1-412.
4. Brock, K.J. 1986. Birds of the Indiana Dunes. Indiana Univ. Press, Bloomington. 68 pp.
5. Buss, I.O. and A.S. Hawkins. 1939. The Upland Plover at Faville Grove, Wisconsin. Wilson Bull. 51:202-220.
6. Butler, A.O. 1898. The birds of Indiana. 22nd Ann. Report Indiana Dept. Geol. and Nat. Res., Indianapolis, p. 727-728.
7. Graber, R.R. and J.W. Graber. 1963. A comparative study of bird populations in Illinois, 1906-1909 and 1956-1958. Illinois Nat. H. Surv. Bull. 28:468-469.
8. Haverschmidt, F. 1966. The migration and wintering of the Upland Plover in Surinam. Wilson Bull. 78:319-320.
9. Higgins, K.F. 1975. Shorebird and game bird nests in North Dakota croplands. Wildlife Soc. Bull. 3:176-179.
10. Kaiser, P.H. 1979. Upland Sandpiper nesting in southeastern South Dakota. Proc. S.D. Acad. Sci. 58:59-68.
11. Kirsch, L.M. and K.F. Higgins. 1976. Upland Sandpiper nesting and management in North Dakota. Wildlife Soc. Bull. 4:16-20.
12. Knodel-Montz, J.J. 1981. Use of artificial perches on burned and unburned tallgrass prairie. Wilson Bull. 93:547-548.
13. Mumford, R.E. and C.E. Keller. 1984. The birds of Indiana. Indiana Univ. Press, Bloomington. 376 pp.
14. Osborne, D.R. and A.T. Peterson. 1984. Decline of the Upland Sandpiper (*Bartramia longicauda*) in Ohio: An endangered species. Ohio J. Sci. 84:8-10.
15. Powell, D.J. 1981. Michigan bird survey, spring, 1981. Jack-Pine Warbler 59:105-112.
16. Swink, F. and Wilhelm, G. 1979. Plants of the Chicago region. Morton Arboretum, Lisle, IL. 922 pp.
17. Tate, J., Jr. 1986. The blue list for 1986. Amer. Birds 40:227-236.
18. White, R.P. 1983. Distribution and habitat preference of the Upland Sandpiper (*Bartramia longicauda*) in Wisconsin. Amer. Birds 37:16-22.

Food and Ectoparasites of Shrews of South Central Indiana with Emphasis on *Sorex fumeus* and *Sorex hoyi*

John O. Whitaker, Jr. and Wynn W. Cudmore[1]
Department of Life Sciences
Indiana State University
Terre Haute, Indiana 47809

Introduction

Although information on shrews of Indiana was summarized by Mumford and Whitaker (1982), the pygmy shrew, *Sorex hoyi*, and smoky shrew, *Sorex fumeus*, were not discovered in Harrison County in southern Indiana (Caldwell, Smith & Whitaker, 1982) until the former work was in press. Cudmore and Whitaker (1984) used pitfall trapping to determine the distributions of these two species in the state. The two had similar ranges, occurring from Perry, Harrison and Clark counties along the Ohio River north to Monroe, Brown and Bartholomew counties (*S. hoyi* ranging into extreme SE Owen County). This is essentially the unglaciated "hill country" of south central Indiana where *S. fumeus* and *S. hoyi* occur on wooded slopes whereas *S. longirostris* inhabits bottomland woods (Whitaker & Cudmore, in preparation).

Information on food and ectoparasites of *Blarina brevicauda*, *S. cinereus* and *S. longirostris* from Indiana was summarized by Mumford and Whitaker (1982), and more data on the latter two species were presented by French (1982, 1984). Additional information on ectoparasites of these species, other than for *Sorex longirostris*, was reported from New Brunswick, Canada, by Whitaker and French (1982).

The purpose of this paper is to present information on the food and ectoparasites of shrews of south central Indiana.

Materials and Methods

Pitfall traps (1000 ml plastic beakers) were used to collect shrews. The traps were sunk under or alongside logs in woods so that their rims were at ground level. They were placed in lines with the spacing and number dependent on the number and distribution of logs, and were left in place an average of 31 days (range 16-49). About 3 cm of water was placed in the beakers which were then checked once or twice per week.

Thirty-five localities in 21 southern Indiana counties were sampled in this fashion. Habitat relationships of these shrews will form the basis for a separate paper. However, all traps were in deep woods, ranging from Oak-Hickory to Beech-Maple forest. *Blarina* occurred throughout the area. *Sorex fumeus* and *S. hoyi* occurred on the uplands and slopes of the unglaciated hill country, whereas *Sorex cinereus* was absent from that area. *Sorex cinereus* was the only long-tailed shrew to occur in southeastern Indiana east of the unglaciated area (see Cudmore & Whitaker, 1984), whereas *S. cinereus* occurred in the bottomlands and *S. longirostris* occurred in the uplands in southwestern Indiana (west of the unglaciated hill country) (see French, 1980).

Most of the shrews for this study were collected between the fall of 1982 and June 1983. An average of 19 traps (6-40) was used per site. Shrews were taken as follows: Short-tailed Shrew, *Blarina brevicauda* (n = 299), Smoky Shrew, *Sorex fumeus* (n = 108), Pygmy Shrew, *Sorex hoyi* (n = 73), Southeastern Shrew, *Sorex longirostris* (n = 76), and Masked Shrew, *Sorex cinereus* (n= 98).

---

[1] Present address: Chemeketa Community College, 4000 Lancaster Drive N.E., P.O. Box 14007, Salem, Oregon 97309.

It is well known that shrews deteriorate quickly after death, especially in warm weather. This raises the question of suitability of the shrews for research puroses when they were allowed to remain in the pitfall traps for several days. Much of the present work was done in cool weather. However, even in warm weather, many of the shrews were still suitable for study, and many were preserved as study skins. Stomach contents of many could be examined, and ectoparasites from many could be collected (Tables 1-5). The water in the beakers apparently helped to preserve the shrews by excluding air. We suspect that the parasite numbers are somewhat low, because some may have been lost in the water. Also, there is some chance for mixing of parasites between hosts, but we found little evidence of this. There were no cases of numbers of host specific species being on the wrong host. Information on foods eaten was gathered on all four shrew species, whereas information on ectoparasites was gathered only on *S. hoyi* and *S. fumeus* from this sample.

Stomachs were removed from shrews, their contents immersed in water and identified under a dissecting microscope; volumes were visually estimated. Food habits data were summarized as percent volume (percent total volume each food comprised) and percent frequency (percent of shrews having eaten each food). A one-way ANOVA with Duncan's Multiple Range Test was used to test for significant differences among food groupings using raw data and the 95% significance level. The ANOVA was conducted on transformed data (equal to the arcsine of the square root of the percentage estimate).

Ectoparasites were collected from the fur and skin of *S. fumeus* and *S. hoyi* with the aid of a 10-70 power zoom dissecting microscope. A probe was used to manipulate the fur, and parasites were removed with watchmakers forceps, preserved in 70% ethanol, cleared and stained in Nesbitt's solution and mounted in Hoyer's solution. Ectoparasites were counted when possible, or their numbers visually estimated when numbers were large. Data on ectoparasites were presented as average number per host, based on all hosts, and percent of hosts infected. Information on ectoparasites previously collected from Indiana *S. cinereus*, *S. longirostris* and *B. brevicauda* (Mumford and Whitaker, 1982; French, 1982) was used for comparison.

Results

Food

Information on foods consumed by the five species is presented in Table 1, and

TABLE 1. Food of five species of shrews from south central Indiana (numbers in parentheses are subtotals for insect larvae and beetles).

	Blarina brevicauda		*Sorex fumeus*		*Sorex longirostris*		*Sorex cinereus*		*Sorex (Microsorex) hoyi*	
n =	150		82		69		71		63	
	% vol	% freq	% vol	% freq	% vol	% freq	% vol	% freq	% vol	% freq
Earthworms (Annelida)	38.9	48.7	16.1	23.2	3.8	4.3	4.1	8.5		
Slugs & Snails (Mollusca)	9.3	12.0	2.1	3.7	1.2	1.4	0.2	1.4		
Centipedes (Chilopoda)	3.0	6.0	15.1	30.4	5.1	11.6	3.7	8.5	1.5	7.9
Insect larvae										
Unidentified	5.4	7.3	6.5	12.2	3.9	8.7	7.6	12.7	8.4	15.9
Tipulid larvae	3.7	5.3	1.6	2.4	1.4	1.4	0.2	1.4	3.2	4.8
Dipteran larvae	3.3	6.7	2.7	8.5	4.3	7.2	7.5	11.3	2.4	3.2
Coleopteran larvae	3.1	6.7	6.7	14.6	5.1	7.2	4.2	4.2	5.6	11.1
Bibionid larvae	2.9	3.3							1.6	1.6
Lepidopteran larvae	2.2	3.3	3.8	11.1	6.7	13.0	3.9	4.2	6.7	7.9

TABLE 1.—Continued

	Blarina brevicauda		*Sorex fumeus*		*Sorex longirostris*		*Sorex cinereus*		*Sorex (Microsorex) hoyi*	
n =	150		82		69		71		63	
	% vol	% freq	% vol	% freq	% vol	% freq	% vol	% freq	% vol	% freq
Scarabaeid larvae	0.9	2.0	1.2	1.2	1.2	1.4	4.2	4.2	1.6	1.6
Neuropteran larvae	0.7	0.7								
Stratiomyid larvae	0.5	0.7								
Chironomid larvae	0.1	0.7			0.1	1.4	0.1	1.4		
Elateridae							1.8	2.8		
Chauliognathodes			1.6	2.4						
	(22.8)		(24.1)		(22.7)		(29.5)		(29.5)	
Beetles (Coleoptera)										
Unidentified	6.4	14.7	5.4	17.0	7.2	13.0	5.7	11.3	14.7	19.0
Carabidae	2.8	4.0	1.2	2.4			0.7	1.4	4.4	6.3
Scarabaeidae	0.7	0.7	3.1	4.9					0.1	1.6
Curculionidae	—	—			—	—	0.2	1.4	—	—
Bostrichidae	—	—			—	—			1.3	1.6
	(9.9)		(10.7)		(7.2)		(6.6)		(20.5)	
Mast	2.3	3.3			1.6	2.9	2.8	2.8	1.0	1.6
Isopods, Isopoda	1.9	2.7	0.6	3.7	0.3	1.4	0.3	4.2	1.5	1.6
Endogone	1.7	4.0	2.0	4.9						
Spider	1.5	2.7	12.4	26.8	36.1	47.8	31.3	42.3	25.4	31.7
Lepidopterous pupae	1.5	2.0	1.2	1.2						
Mammal	1.3	1.3							2.1	4.8
Unidentified insect	1.0	6.0							2.1	7.9
Salamander	0.7	0.7								
Hemiptera	0.7	0.7	0.9	3.7	0.2	1.4	0.1	2.8		
Orthopteran eggs	0.6	0.7								
Ants (Formicidae)	0.6	2.0	1.2	2.4	0.9	1.4	0.4	1.4	4.5	6.3
Moths (Lepidoptera)	0.6	0.7	4.7	4.9			2.8	5.6	0.6	1.6
Vegetation	0.5	10.7	0.1	1.2					0.01	1.6
Harvestmen (Phalangida)	0.4	0.7	0.1	1.2	1.4	1.4	1.5	2.8	0.3	1.6
Flies (Diptera)	0.2	2.0	1.3	8.5	2.0	5.8	5.2	14.1	3.5	7.9
Unidentified invertebrate	0.2	0.7	2.8	9.8	8.3	17.4	2.7	11.3		
Unidentified fungus	0.1	0.7								
Crickets (Gryllidae)	0.1	0.7	2.1	6.1	2.7	5.8	2.6	2.8	3.1	7.9
Green Pentatomidae (Stinkbugs)	0.03	0.7	0.7	1.2	2.1	5.8	3.5	4.2		
Moss							0.2	1.4		
Sciaridae			1.0	2.4			0.1	1.4		
Vertebrate flesh							2.1	2.8		
Craneflies (Tipulidae)					1.2	1.4			1.6	1.6
Lanternflies (Fulgoridae)					0.9	1.4				
Homoptera					0.9	1.4				
Roaches (Blattidae)					0.5	1.4				
Leafhoppers (Cicadellidae)					0.4	1.4				
Miridae					0.2	1.4				
Mite					0.03	1.4				
Hymenoptera									1.3	1.6
Unidentified									1.6	1.6
Lygaeidae			0.5	3.7						
Aphid			0.02	1.2						
	99.8		99.7		99.7		99.8		100.1	

the major food groupings (those comprising at least 8% of the volume in any one species) in Table 2.

TABLE 2. Major food groups of southern Indiana shrews (% volumes). Lines connect values not differing significantly at $P \leq .05$ (ANOVA + Duncan's Multiple Range Tests).

	Blarina brevicauda	*Sorex fumeus*	*Sorex longirostris*	*Sorex cinereus*	*Sorex (Microsorex) hoyi*
n =	150	82	69	71	63
Earthworm	38.9	16.1	3.8	4.1	—
Insect larvae	22.8	24.2	22.9	29.5	29.4
Beetles	9.9	10.7	7.2	6.6	20.4
Slugs & Snails	9.3	2.1	1.2	0.2	—
Spider	1.5	12.4	36.1	31.3	25.4
Centipede	3.0	15.1	5.1	3.7	1.5

The most important foods of *Blarina brevicauda* listed by order of decreasing percent volume were earthworms, insect larvae, beetles, and slugs and snails. These items comprised 80.9% of the total volume of food in the sample. The five most important foods of smoky shrews were insect larvae, earthworms, centipedes, spiders, and beetle adults. Adult moths were consumed more (4.7% volume, 4.9% frequency) than in any other shrew species. The primary foods of the masked shrew were spiders, insect larvae, beetle adults, and flies, while for *Sorex longirostris* and *S. cinereus*, they were spiders and insect larvae, followed by beetle adults and centipedes. The primary foods of the pygmy shrew were insect larvae, spiders and beetle adults. Adult beetles ranked much higher than in either of the other two small shrew species and ants (Formicidae) were consumed more (4.5% of the volume) than in any other species.

There were significant differences in the amounts of earthworms eaten by the various species ($F = 28.708$, $df = 4$). *Blarina* ate significantly more earthworms than any other species. *Sorex fumeus* ate significantly less earthworms than *Blarina* but significantly more than the other shrews. *Blarina* ate significantly more slugs and snails than any of the other four species ($F = 5.702$, $df = 4$), but there were no significant differences among any of the other species. There were no significant differences among the five species in the amount of insect larvae eaten ($F = 0.636$, $df = 4$). Pygmy shrews consumed significantly greater amounts of adult beetles than any other species ($F = 2.920$, $df = 4$). *Sorex longirostris*, *S. cinereus* and *S. hoyi* did not differ significantly from each other in the amount of spiders eaten, but each consumed significantly more spiders than did *S. fumeus* or *Blarina*, and *S. fumeus* ate significantly more spiders than did *Blarina* ($F = 20.223$, $df = 4$). Centipedes were eaten in significantly greater amounts by *S. fumeus* ($F = 67.835$) than by any other species; there were no significant differences among the other species.

The shrews included in this study were of four distinct size classes. The largest, the short-tailed shrew, which averages about 17.0 (Mumford & Whitaker, 1982), then the smoky shrew, at about 7.2 (our data, $n = 87$, range 4.7-10.7, $SD = 1.46$). The masked shrew and southeastern shrew are the closest in size, averaging about 3.7 and 3.1 grams respectively (Mumford & Whitaker, 1982), whereas the pygmy shrew *S. hoyi* is the smallest and generally weighs about 2.2-6 grams (Long, 1974). The Indiana pygmy shrews are the smallest known pygmy shrews, however. Our specimens averaged about 2.1 grams ($n = 65$, $SD = 0.4$, $SE = 0.049$).

Ectoparasites

Data are presented here on ectoparasites of *Sorex fumeus* and *Sorex hoyi* from Indiana (Tables 3-5). Data on ectoparasites of *B. brevicauda*, *S. cinereus* and *S. longirostris* by Whitaker and Mumford (1972), and on *S. cinereus* and *S. longirostris* by French (1982), from Indiana will be used for comparison.

During the present study, a total of 9 taxa of ectoparasites was found on 9 of 10 southeastern shrews examined. Ectoparasites were (x̄, % infested in parentheses) *Orycteroxenus soricis* (x̄ = 14.1, 40.0% infested), *Bakerdania* sp. (1.6, 30.0), *Protomyobia indianensis* (1.3, 40.0), *Amorphacarus hengererorum* (1.3, 20.0), and the following with one individual each (0.1, 10.0): *Androlaelaps fahrenholzi*, *Pygmephorus hastatus*, *Cyrtolaelaps* sp., *Proctolaelaps* sp., and one *histiostomatid*. These limited data are similar to previous Indiana information from this host (French, 1982; Whitaker and Mumford, 1972). It would be desirable to obtain additional data for *Blarina* and *S. longirostris* for south central Indiana.

Sorex (*Microsorex*) *hoyi*

An estimated 11,554 ectoparasites (x̄ = 340/individual) were recovered from a sample of 34 pygmy shrews (Table 3). Thirty-two (94.1%) of the shrews yielded ectoparasites.

TABLE 3. Ectoparasites and other associates of 34 Pygmy Shrews, *Sorex* (*Microsorex*) *hoyi*, from south central Indiana.

	Number		Number infested	
	N	x	N	%
Orycteroxenus soricis	11522	338.9	30	88.2
Pygmephorus whitakeri	8	0.2	5	14.7
Comatacarus americanus	7	0.2	2	5.9
Euschoengastia jamesoni	3	0.1	2	5.9
Pygmephorus proctorae	3	0.1	3	8.8
Pygmephorus spinosus	3	0.1	2	5.9
Pygmephorus moreohorridus	2	0.1	1	2.9
Bakerdania sp.	2	0.1	1	2.9
Cyrtolaelaps sp.	2	0.1	1	2.9
Xenoryctes nudus	1	0.03	1	2.9
Histiostomatidae	1	0.03	1	2.9
	11554			

Only 1 species of mite, the hypopus stage of *Orycteroxenus soricis*, phoretic rather than parasitic, was very common on pygmy shrews. It was found on 30 (88.2%) of the 34 individuals examined (Table 4). Numbers ranging from 1 to an estimated 1000 individuals were found per shrew.

Twenty individuals of *Pygmephorus* were taken, representing 4 species, and 2 species of chiggers, *Euschoengastia jamesoni* (3 individuals) and *Comatacarus americanus* (7 individuals) were taken. The latter species had not previously been recorded from Indiana. The only other forms taken were 1 or 2 individuals of *Bakerdania*, *Cyrtolaelaps*, Histiostomatidae, and *Xenoryctes nudus*.

Sorex fumeus

Seventy-one smoky shrews were examined for ectoparasites, of which 67 (94.4%) harbored a total of 4810 (x̄ = 68/individual) parasites or other associates (Table 4). Most

Table 4. Ectoparasites of the Smoky Shrew, *Sorex fumeus*, from south central Indiana (n = 71).

	Parasites		Hosts infested	
	Number	Av #/host	No.	Percent
Amorphacarus hengererorum	2568	36.2	17	23.9
Euschoengastia whitakeri	939	13.2	27	38.0
Orycteroxenus soricis	533	7.5	11	15.5
Xenoryctes nudus	275	3.9	11	15.5
Euschoengastia jamesoni	167	2.4	29	40.8
Protomyobia brevisetosa	68	1.0	12	16.9
Bakerdania sp.	43	0.6	16	22.5
Cyrtolaelaps sp.	27	0.4	18	25.4
Histiostomatidae	27	0.4	19	26.8
Neotrombicula cavicola	24	0.3	4	5.6
Xenoryctes latiporus	18	0.3	6	8.5
Pygmephorus hastatus	17	0.2	10	14.1
Pygmephorus rackae	13	0.2	8	11.3
Pygmephorus whitakeri	12	0.2	6	8.5
Dermacentor variabilis	11	0.2	2	2.8
Echinonyssus blarinae	11	0.2	8	11.3
Echinonyssus talpae	9	0.1	3	4.2
Doratopsylla blarinae	7	0.1	5	7.0
Proctolaelaps sp.	6	0.1	5	7.0
Androlaelaps fahrenholzi	5	0.1	5	7.0
Pygmephorus horridus	4	0.1	4	5.6
Pygmephorus brevicaudae	3	0.04	3	4.2
Pygmephorus spinosus	3	0.04	1	1.4
Euryparasitus sp.	3	0.04	3	4.2
Pygmephorus hamiltoni	2	0.03	2	2.8
Pygmephorus equitrichosus	2	0.03	1	1.4
Eucheyletia bishoppi	2	0.03	2	2.8
Leptinus americanus	2	0.03	2	2.8
Glycyphagus hypudaei	1	0.01	1	1.4
Pygmephorus lutterloughae	1	0.01	1	1.4
Pygmephorus faini	1	0.01	1	1.4

abundant was the myobiid mite, *Amorphacarus hengererorum*, followed by the chigger, *Euschoengastia whitakeri*, the glycyphagid hypopi *Orycteroxenus soricis* and *Xenoryctes nudus*, and another chigger, *Euschoengastia jamesoni*. Thirty-one ecoparasite taxa were recovered from *S. fumeus*.

Four species of chiggers were found on *S. fumeus*, but *Euschoengastia whitakeri* and *E. Jamesoni* were the most abundant species. *Euschoengastia whitakeri* was discovered during this study and has recently been described as new (Wrenn, 1984). *E. Jamesoni* and *N. cavicola* had not been previously taken from Indiana.

Glycyphagid hypopi were prominent on *S. fumeus* although they were not as abundant as on *S. hoyi*. The most abundant species was *Orycteroxenus soricis* with an estimated total of 533 individuals, 500 on one animal. *Xenoryctes nudus* and *X. latiporus* were also often taken, and collectively, were taken on more individuals (14) than was *O. soricis*.

The sixth most abundant form on *S. fumeus* was the myobiid mite, *Protomyobia brevisetosa*. It is restricted to *S. fumeus* in the east but is widespread on *Sorex* in the western United States. Mites of the family Pygmephoridae (*Bakerdania* and *Pygmephorus*) were common. *Bakerdania* sp. probably included several species. *Pygmephorus* was represented by 11 species. Two species of *Echinonyssus* were taken: *E. talpae*, of several species of shrews, and *E. blarinae*, usually found on *Blarina*. A few fleas, 7 individuals of *Doratopsylla blarinae* and 1 of *Ctenophthalmus pseudagyrtes*, were taken, as were 2 individuals of the beetle parasite, *Leptinus americanus.*

Eight species of ectoparasites were taken from Indiana for the first time during this study. They consist of four chiggers, *Euschoengastia whitakeri* from *S. fumeus*, *E. jamesoni* from *Sorex fumeus* and *S. hoyi*, *Neotrombicula cavicola* from *S. fumeus*, and *Comatacarus americanus* from *S. hoyi*; the glycyphagid mite *Xenorcytes nudus* and the myobiid mite *Protomyobia brevisetosa* from *S. fumeus*; and *Pygmephorus lutterloughae* from *S. fumeus* and *P. proctorae* from *S. hoyi.*

The 17 most abundant species of ectoparasites (those occurring at rates of at least 0.3/shrew on any one species) are listed in Table 5. Only one species, *Orycteroxenus soricis*, occurred on all five hosts. *Androlaelaps fahrenholzi* occurred on four of the shrew species and was a major species on two, whereas *Xenoryctes nudus* occurred on four but was a major parasite on only one. *Amorphacarus hengererorum* was a major parasite on all three on which it occurred.

A simple coefficient was developed to assess similarities and differences between the parasite communities. Complete or 100% similarity would mean that all 17 parasites

TABLE 5. Major species of ectoparasites of shrews of Indiana (those occurring at rates of at least 0.3/individual of any one host species, expressed as Av. #/individual). (Data for *Sorex cinereus* and *S. longirostris* are from French, 1982; those from *Blarina* are from Whitaker & Mumford, 1972.)

		Sorex				Number of Shrew Species	
	Blarina	*fumeus*	*cinereus*	*longi-rostris*	*hoyi*	on which it occurs	on which it occurs as major species
n =	92	71	58	41	34		
Fleas							
Ctenophthalmus pseudagyrtes	0.3	0.01	0.07	—	—	3	1
Corrodopsylla curvata			0.7	—		1	1
Myobiid Mites							
Amorphacarus hengererorum	—	36.2	0.9	5.2	—	3	3
Protomyobia brevisetosa	—	1.0			—	1	1
P. indianensis	—	—	—	1.4	—	1	1
P. claparedei	—	—	1.8	—	—	1	1
Trombiculid Mites (Chiggers)							
Euschoengastia whitakeri	—	13.2			—	1	1
E. jamesoni		2.4			0.1	1	1
Neotrombicula cavicola	—	0.3			—	1	1
Glycyphagid mites							
Orycteroxenus soricis	13.5	7.5	162.6	59.1	338.9	5	5
Xenoryctes nudus	—	3.9	0.1	0.1	0.03	4	1
X. latiporus	—	0.3	0.03	0.1	—	3	1
Glycyphagus hypudaei			0.1	1.2		2	1
Laelapid mites							
Androlaelaps fahrenholzi	0.7	0.1	0.1	0.3		4	2
Myonyssus jamesoni	0.3	—				1	1
Haemogamasus liponyssoides	0.3	0.01	0.05	—		3	1
Listrophorid mites							
Asiochirus blarinae	28.4	—			—	1	1
						36	24

would occur as major forms on all five shrew species. In that case the total in the last column of Table 5 would be 85. Zero similarity would be indicated by a one in every row for a total of 17. The similarity coefficient was calculated as $((T - 17)/68) \times 100$ would be 100% when $t = 85$ and zero when $t = 17$. (Complete similarity would actually, of course, require that the numbers per host not differ significantly also, but that factor was ignored here.)

The similarity coefficient for major parasites in the shrews under study here was only 10.3%; for simple occurrence the similar value was 27.9%. These values indicate rather dissimilar parasite communities on the five species of shrews.

The ectoparasites occurring at rates of 1.0 or more per host are lited below. They are:

B. brevicauda:	*Asiochirus blarina*, *Orycteroxenus soricis*
S. fumeus:	*Amorphacarus hengererorum*, *Euschoengastia whitakeri*, *O. soricis*, *Xenoryctes nudus*
S. cinereus:	*O. soricis*, *Protomyobia claparedei*
S. longirostris:	*O. soricis*, *A. hengererorum*, *Protomyobia indianensis*, *Glycyphagus hypudaei*
S. hoyi:	*O. soricis*

The commonest species is *Orycteroxenus soricis*, which is the most abundant form in the three smallest shrews, second in *Blarina* and third in *S. fumeus*. It was the only species occurring at a rate over 1.0 in *S. hoyi*. *Amorphacarus hengererorum* was most abundant in *S. fumeus* and second in abundance in *S. longirostris*. All other species occurred on one host only.

The species of shrews of the hill country of south central Indiana, when they occur together, eat many of the same foods but differ considerably in proportions and harbor rather different ectoparasite communities.

Discussion

The five species of shrews under consideration show patterns of variation in size and in food habits, and also of ecological and geographical replacement, all of which should reduce competition and allow them to live in the same general region. *Blarina* is the largest of the species and occurs throughout the area but, unlike the other species, feeds heavily on earthworms. It differed the most in food habits from any other species. *Sorex cinereus* is very similar in size and food habits to *Sorex longirostris* but does not occur in the unglaciated region. Of the three species other than *Blarina* that live in the unglaciated region, the largest and smallest live on the slopes and in the ravines and eat quite different foods (more beetles and spiders in *S. hoyi*, more earthworms and centipedes in *S. fumeus*) whereas *Sorex longirostris* occupies the flatlands.

The foods of the three smallest species, *S. cinereus*, *S. longirostris* and *S. hoyi*, are very similar, but the three are separated in southern Indiana geographically and/or ecologically. French (1984) found *Sorex cinereus* in the bottomlands and *S. longirostris* in the uplands in SW Indiana (west of the unglaciated area). We found *Sorex fumeus* and *S. hoyi* on the uplands, *S. longirostris* on the bottomlands in the unglaciated area. It seems highly likely that this geographical/ecological separation has been highly influenced if not caused by competitive exclusion.

There were pronounced differences between the ectoparasite communities of the shrews under study here. We believe these differences in great part reflect differing habits and habitats of the hosts. Data on chiggers, in particular, support this logic. Chiggers are basically non-host specific. Many of them do occur on one or few hosts, not because of host specificity as we usually think of it (inability to tolerate conditions on other hosts) but because they live in a situation where it is unlikely that different hosts will pick them up. For this reason, they could be termed habitat specific (Loomis, 1956). Thus, if two species of shrews spend much time in the same place and under the same conditions, their chigger communities should be quite similar. However, *S. hoyi* had few chiggers, whereas *S. fumeus* had many. In addition, the most abundant chigger of *S. hoyi* was *Comatacarus americana* (seven individuals taken at two sites), whereas this species was not found on *S. fumeus*. The most abundant chigger on *S. fumeus* was *Euschoengastia whitakeri* ($\bar{x} = 13.2$), but this chigger did not occur on any other host. *Euschoengastia jamesoni* was found at a rate of 2.4 on *S. fumeus*, and 0.1 on *S. hoyi* but was not found on any other host. Likewise, *Comatacarus* occurred only on *S. hoyi*, and *Neotrombicula cavicola* only on *S. fumeus*. The ectoparasites of *S. hoyi* seem to show a depauperate fauna, although the chigger, *Comatacarus americana*, was found only on this species and on no other in Indiana. This may indicate some ecological specialization of this shrew.

Mites of the family Pygmephoridae (*Pygmephorus* and *Bakerdania*) are often common on insectivores, but are not host specific (Smiley & Whitaker, 1978; Whitaker, French & Smiley, 1982). Eleven species of *Pygmephorus* were taken on *Sorex fumeus*, and four on *S. hoyi* during the present work. Three of the four taken on *S. hoyi* were also taken on *S. fumeus*. Few species of *Bakerdania* have been described from North America to date, but Mahunka and Whitaker are currently in the process of describing a number of species.

Acknowledgments

We thank William H. Kern and Barbara A. Brown of Indiana State University and Larry Allsop and Rick Pearcy of Crosley State Fish and Wildlife Area for their generous help with the field work. Mr. Milton Firestone of the Indiana State University Computer Center helped with the statistical analysis.

Literature Cited

Caldwell, R.S., C.K. Smith and J.O. Whitaker, Jr. 1982. First records of the smoky shrew, *Sorex fumeus*, and pygmy shrew, *Microsorex hoyi*, from Indiana. Proc. Ind. Acad. Sci. 91: 606-608.

Cudmore, W.W., and J.O. Whitaker, Jr. 1984. The distribution of the smoky shrew, *Sorex fumeus*, and the pygmy shrew, *Microsorex hoyi*, in Indiana with notes on the distribution of other shrews. Proc. Ind. Acad. Sci. 93: 469-474.

French, T.W. 1980. Ecological relationships between the southeastern shrew (*Sorex longirostris* Bachman) and the masked shrew (*S. cinereus* Kerr) in Vigo County, Indiana. Unpubl. Ph.D. dissertation. Indiana State University. 54 p.

French, T.W. 1982. Ectoparasites of the Southeastern Shrew, *Sorx longirostris*, and the Masked Shrew, *Sorex cinereus*, in Vigo County, Indiana, USA. J. Med. Entomol. 19: 628-630.

French, T.W. 1984. Dietary overlap of *Sorex longirostris* and *S. cinereus* in hardwood floodplain habitats in Vigo County, Indiana. Amer. Midl. Nat. 111: 41-46.

Long, C.A. 1974. *Microsorex hoyi* and *Microsorex thompsoni*. Mamm. Species 33: 1-4.

Loomis, R.B. 1956. The chigger mites of Kansas (Acarina, Trombiculidae). Univ. Kansas Sci. Bull. 37: 1195-1443.

Mumford, R.E. and J.O. Whitaker, Jr. 1982. Mammals of Indiana. Indiana University Press. Bloomington. 537 p.

Smiley, R.L. and J.O. Whitaker, Jr. 1978. Mites of the genus *Pygmephorus* (Acari: Pygmephoridae) on small mammals in North America. Acta Zool. Acad. Scient. Hungarica 25: 383-408.

Whitaker, J.O. Jr., and T.W. French. 1982. Ectoparasites and other associates of some insectivores and rodents from New Brunswick. Canad. J. Zool. 60: 2787-2797.

Whitaker, J.O. Jr., and R.E. Mumford. 1972. Food and ectoparasites of Indiana shrews. J. Mamm. 53: 329-335.

Whitaker, J.O. Jr., T.W. French and R.L. Smiley. 1982. Notes on host relationships and host specificity of mites of the genus *Pygmephorus* (Acari: Pygmephoridae) on insectivores and rodents from Mount Carleton Provincial Park, New Brunswick. Internat. J. Acarol. 8: 233-235.

Wrenn, W.J. 1984. *Euschoengastia whitakeri* n. sp. (Acari: Trombiculidae) from the Smoky Shrew in Indiana. Internat. J. Acarol. 10: 15-18.

Fishes of Goose Pond and Its Drainge Basin

Rusty K. Yeager, David S. Nichols, Susan J. Schultheis, Michael T. Galbraith,
Susan E. Lenn and Thomas H. Cervone
University of Southern Indiana
Evansville, Indiana 47712

Introduction

Goose Pond is geographically located 6.4 kilometers southeast of Mount Vernon in Black Township (Posey County) of southwestern Indiana. It lies within unglaciated terrain of the Wabash Lowland Region (19) in the Caborn Quadrangle (T7S, R13W, S14/23). Elevations within the drainage basin range from 107 to 113 meters above sea level.

Goose Pond is a lacustrine ecosystem situated in Cypress Slough, a large, shrub swamp covering 26.3 hectares dominated by buttonbush with some black willow and green ash (10) and drains an area of 67 square kilometers (5) before entering the Ohio River. Goose Pond covers 6 hectares of it and is lined by buttonbush and bald cypress, while its two neighboring, palustrine ponds cover areas of 3.2 and 1.0 hectares (Figure 1). Agricultural lands surround the Goose Pond basin.

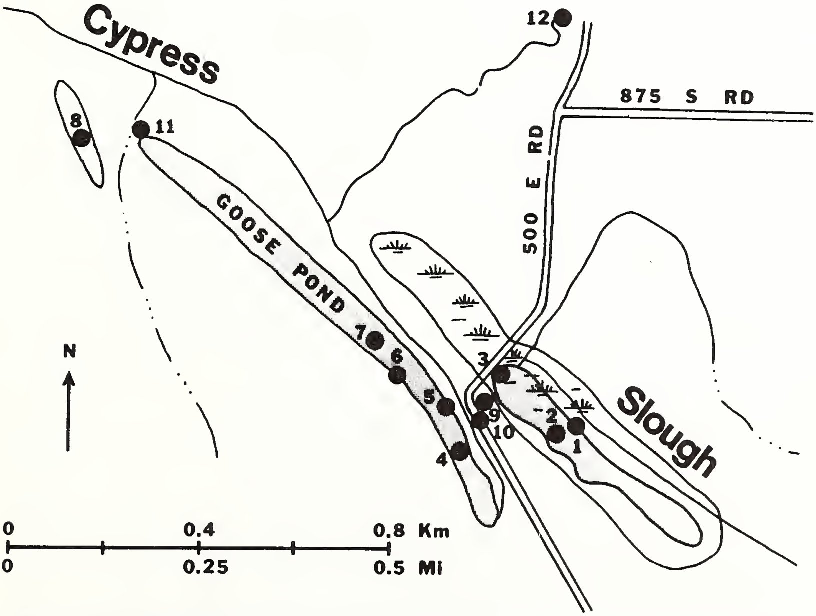


Figure 1. Map of Goose Pond and its drainage basin. Solid circles represent collecting sites.

Few ichthyological studies have been published on flood ponds or lakes in southwestern Indiana. Goose Pond was sampled in the summer of 1980 (8), while Hovey Lake (located 16 kilometers south of Mount Vernon, IN), a larger but similarly positioned lacustrine wetland, was investigated in 1942 (3). Fishes of Foots Pond, located in southwestern Indiana (Gibson County), was investigated in 1940-1941 (6, 9). To our knowledge, no other studies have been published.

The purpose of this study was to obtain base-line information on the type, relative abundance, distribution and species diversity of fishes in the Goose Pond drainage basin during winter to early spring of 1986. A secondary objective was to compare our results with the summer investigation of Goose Pond in 1980 (8).

Materials and Methods

Twelve sites were sampled within the Goose Pond drainage basin (Figure 1) from 23 February to 1 April 1986. Fishes were collected using a combination of or singly a gill net (26.3 × 1.4 meter - 4 cm diamond mesh), hoop net (3.0 meter long × 0.6 meter diameter - 3 cm diamond mesh; 2 wings and 1 lead of 2.0 × 0.5 meter - 2 cm diamond mesh) and various-sized seines. They were a cast seine (1.8 meter diameter - 4 cm diamond mesh, bag seine (2 wings 3.0 × 1.2 meter; bag 1.2 × 1.2 meter - 1 cm diamond mesh), 4.3 × 1.2 meter seine (0.5 cm square mesh), and two 1.7 × 1.1 meter seines (0.3 and 0.6 cm ace mesh). Fishes were preserved in the field in 10% formalin following capture. Specimens are presently housed within the University of Southern Indiana collection.

Species diversity was determined using the Shannon-Weaver function (H′): $H' = C/N\,(N \log_{10} N - \Sigma\, n_i \log_{10} n_i)$, where $C = 3.32$ (the constant for conversions of logarithms from base 10 to base 2); N equals the total number of individuals in the population; and n_i is the number of individuals of a particular species (4). Results are independent of sample size (15).

Fishes were keyed to species using standard references (1, 11, 14, 17, 18). All scientific and common names in this report are currently acceptable names (16).

Results

Twenty-nine species of fish from 13 families were collected in the Goose Pond drainage basin (Figure 1). Fishes were collected from 3 distinct habitats. They were the open water ponds, wooded natural channels and tributary. The distribution and relative abundance of these species are shown in Table 1.

Distribution of fishes in the basin showed the emerald shiner as the dominant fish in the pond, channel and tributary habitats. The open water pond produced many gizzard shad too accompanied by, in fewer numbers though, the orangespotted sunfish, white crappie, bluegill, brook silverside and golden shiner. The emerald shiner and brook silverside were especially abundant at Stations 8 and 10, while the white crappie was for the most part collected along the buttonbush shores of Goose Pond. Inasmuch as the orangespotted sunfish and bluegill were collected together, their numbers were not the same. The orangespotted sunfish outnumbered the bluegill in the pond habitat, while the bluegill outnumbered the orangespotted sunfish in the channel habitat ($X^2 = 128.7$; df = 1; $p < .001$). Mosquitofish were found in both the channel and tributary habitats. In contrast, the spotfin shiner and blackstripe topminnow were collected predominately in the tributary. Incidental species with 7 or fewer individuals in the basin were the spotted gar, bowfin, grass pickerel, mississippi silvery minnow, river shiner, sand shiner, mimic shiner, bluntnose minnow, creek chub, smallmouth buffalo, bigmouth buffalo, yellow bullhead, green sunfish, warmouth, largemouth bass, black crappie, mud darter, slough darter and freshwater drum.

The most abundant fish in the basin was the emerald shiner. It comprised 51.4% of the total collection. Other fishes relatively abundant were the bluegill (15.8%), gizzard shad (11.6%), orangespotted sunfish (7.5%), white crappie (3.5%), brook silverside (2.3%) and golden shiner (1.7%). Together, these 7 species comprised 93.8% of the total catch, while the remaining 22 species made up 6.2%. The most common families represented were the minnow (55.0%), sunfish (27.7%) and herring (11.6%). Fishes from these families comprised 94.3% of the total catch, while disporportionately, the remain-

TABLE 1. Frequency, Location and Diversity of Fish Species in the Goose Pond Drainage Basin per Station.

	Pond								Channel			Trib.	Total	% of Total Catch	% Frequency of Occurrence
Stations	1	2	3	4	5	6	7	8	9	10	11	12			
Species															
Lepisosteus oculatus (Spotted Gar)							1						1	0.1	8.3
Amia calva (Bowfin)							3						3	0.2	8.3
Dorosoma cepedianum (Gizzard Shad)		7	8	2	2	5	163	10		2			199	11.6	66.7
Esox americanus (Grass Pickerel)						1							1	0.1	8.3
Hybognathus nuchalis (Miss. Silvery Minnow)										1		1	2	0.1	16.7
Notemigonus crysoleucas (Golden Shiner)			5	1				19		2		3	30	1.7	41.7
Notropis atherinoides (Emerald Shiner)				6	18			374		457		24	879	51.4	41.7
Notropis blennius (River Shiner)				2						1		1	4	0.2	25.0
Notropis spilopterus (Spotfin Shiner)										3		9	12	0.7	16.7
Notropis stramineus (Sand Shiner)				1									1	0.1	8.3
Notropis volucellus (Mimic Shiner)										6			6	0.4	8.3
Pimephales notatus (Bluntnose Minnow)			1	3									4	0.2	16.7
Semotilus atromaculatus (Creek Chub)										1		1	2	0.1	16.7
Ictiobus bubalus (Smallmouth Buffalo)					1		1						2	0.1	16.7
Ictiobus cyprinellus (Bigmouth Buffalo)							1						1	0.1	8.3
Ictalurus natalis (Yellow Bullhead)							1					3	4	0.2	16.7
Fundulus notatus (Blackstripe Topminnow)	1							1		5		12	19	1.1	33.3
Gambusia affinis (Mosquitofish)										5	4	6	15	0.9	25.0
Labidesthes sicculus (Brook Silverside)				1				32		6			39	2.3	25.0
Lepomis cyanellus (Green Sunfish)												1	1	0.1	8.3
Lepomis gulosus (Warmouth)	1				1	1				2			5	0.3	33.3
Lepomis humilis (Orangespotted Sunfish)	9			81	6			1		20	12		129	7.5	50.0
Lepomis macrochirus (Bluegill)	3			35	2	1	1	4	1	219	4		270	15.8	75.0
Micropterus salmoides (Largemouth Bass)				1			1						2	0.1	16.7
Pomoxis annularis (White Crappie)	4		1	1	45	2	4			3			60	3.5	58.3
Pomoxis nigromaculatus (Black Crappie)	1		1	1	1	2			1				7	0.4	50.0
Etheostoma asprigene (Mud Darter)				1									1	0.1	8.3
Etheostoma gracile (Slough Darter)				2						3			5	0.3	16.7
Aplodinotus grunniens (Freshwater Drum)	1				2						2		5	0.3	25.0
Total Number of Species	7	1	5	14	9	6	9	7	2	16	4	10	29		
Total Number of Individuals	20	7	16	138	78	12	176	441	2	736	22	61	1709		
Species Diversity (H′)	2.3	0	1.8	1.9	1.9	2.3	0.6	0.9	1.0	1.5	1.7	2.5			

ing 10 families made up 5.7%. The catfish and sucker families were poorly represented in the basin.

Species diversity in the basin ranged from 0 to 2.5 (Table 1) with an average of 1.5 ± 0.8. The highest species diversity index was found in the tributary (Station 12), while the lowest was found in the eutrophic waters at Station 2. Stations 1, 2 and 3 showed deep, organic sediments.

Discussion

The most abundant fish in the study was the emerald shiner. Its superabundance suggests it as a winter-early spring resident in the Goose Pond basin. In summer though, their numbers in flood ponds in southwestern Indiana decrease (3, 6, 8) concurrent with an increase in their frequency in large rivers (2, 12, 13, 18), like the Ohio River, where it is the most abundant species (12, 13). In fall, the emerald shiner has been observed in large concentrations at the mouth of tributaries of large rivers (7, 12) suggesting a subsequent upstream migration. A fall migration into flood ponds is further supported by their high frequency in this winter-early spring investigation compared with 10 or fewer individuals reported from Goose Pond in the summer of 1980 (8). An even more exaggerated seasonal difference was shown by an absence of emerald shiners in Hovey Lake in the summer of 1942 (3) even though it was abundant in the Ohio River from 1920-1950 (18). Emerald shiners were uncommon in Foots Pond (7) where collections were made in summer and fall (9).

The bluegill, gizzard shad, orangespotted sunfish, white crappie, brook silverside and golden shiner were collected in modest numbers. They are common fishes in sloughs in southwestern Indiana (3, 6, 8) and have been reported previously from Goose Pond (8) with the exception of the brook silverside. We found most of the brook silverside at Station 8 (Figure 1) accompanied by many emerald shiners and some golden shiners. Station 8 was a small, somewhat hidden pond totally surrounded by a thick, wide stand of buttonbush. The pond had a hardpan, calcitic mud bottom and was well protected from holomixis. Such reduced wind effects promoted undisturbed sediments and consequently, reduced turbidity in the pond. Of the three ponds in the basin, this one was the least turbid. The sediment of Goose Pond was soft, calcitic mud and the remaining pond (east of Goose Pond) had deep, organic sediment. Emerald shiners, brook silverside and golden shiners prefer clear waters (17, 18) as was available at Station 8 and to a lesser extent, in the wooded natural channel. Ninety-five percent of the emerald shiners, 97% of the brook silverside and 70% of the golden shiners collected in this study came from Stations 8 and 10. Turbidity was the chief factor for the brook silverside's decline in Illinois (17) and Ohio (18). The emerald shiner and golden shiner are more turbidity tolerant fishes as demonstrated by their higher frequency of occurrence in this study.

In this investigation, the orangespotted sunfish outnumbered the bluegill in the open water pond habitat, while the opposite was true in the wooded natural channel. The bluegill prefers, clear, non-flowing waters with organic debris (1, 14, 17, 18), a habitat which was especially available in the channel. However, Goose Pond and its neighboring pond displayed turbid waters more suitable for the orangespotted sunfish which has a wide ecological tolerance and is usually found in turbid, non-flowing habitats (1, 14, 17, 18). The bluegill was the second most abundant fish in the study.

The gizzard shad was the third most abundant fish in the study. It, like the emerald shiner, shows a strong schooling tendency and is an Ohio River fish (2, 13, 18). The gizzard shad prefers turbid waters with an abundance of phytoplankton (17, 18). It is not surprising then that we found 94% of the gizzard shad, collected for the most part by gill net, in the more turbid waters (with presumably more phytoplankton) of Goose Pond and to a lesser extent, in its neighboring pond (Stations 1 to 7).

Fourteen species were collected for the first time in the Goose Pond drainage basin. They were the grass pickerel, mississippi silvery minnow, river shiner, spotfin shiner, sand shiner, mimic shiner, bluntnose minnow, creek chub, smallmouth buffalo, bigmouth buffalo, brook silverside, largemouth bass, mud darter and slough darter. The low frequency of these fishes suggested a transient status. Such would be expected during flooded times of the year (winter-early spring) in the Goose Pond basin reflective of the rising and lowering of the Ohio River. During such times, it is not inconceivable that many creek and Ohio River fishes are forced or seek refuge in the calmer waters of the Goose Pond basin. Thus, the Goose Pond basin could be viewed as harboring more species at this time than in the summer. This assumption is supported by only 20 species reported in Goose Pond in the summer of 1980 (8) and 24 species from Hovey Lake during the summer of 1942 (3). In contrast, Foots Pond demonstrated 42 species from 14 families when sampled in the summer and fall (6, 9). Our study showed 29 species from 13 families or a 31% increase in richness from the earlier summer investigation (8).

The summer study of Goose Pond (8) reported 5 fishes not collected in this study. They were the shornose gar, carp, brown bullhead, flathead catfish and pirate perch. Of these fishes, the carp was especially abundant which suggested to us depressed summer oxygen levels in Goose Pond. In contrast, our study demonstrated more oxygen sensitive fishes as well as many more gizzard shad, emerald shiner, orangespotted sunfish and bluegill. A 48% difference in the fish community of the Goose Pond basin was shown when our winter-early spring results were compared with those results from the summer of 1908 (8). Fifteen fishes were common to both studies. They were the spotted gar, bowfin, gizzard shad, golden shiner, emerald shiner, yellow bullhead, blackstripe topminnow, mosquitofish, green sunfish, warmouth, orangespotted sunfish, bluegill, white crappie, black crappie and freshwater drum. These fishes are common inhabitants of flood ponds in southwestern Indiana (3, 6, 8).

Conclusion

In Goose Pond and its drainage basin, 29 species of fish from 13 families were collected during the winter to early spring of 1986. The emerald shiner was the most abundant species. Other moderately abundant fishes were the bluegill, gizzard shad, orangespotted sunfish, brook silverside and golden shiner respectively. When compared with an earlier 1980 summer study of fishes in Goose Pond, this investigation showed a 31% increase in richness and a 48% difference in fish community composition. Such differences appeared seasonal and reflect the dramatic interplay adjacent rivers and creeks have on increasing and altering fish communities in flood ponds during flooded times of the year.

Acknowledgments

We would like to express our gratitude to the following persons without whose talent and support this project would not have been possible: Marie E. Cervone, Melvin W. Denner, Anna M. Glaser, Frank L. Stanonis, the students of the 1986 Aquatic Biology Class (University of Southern Indiana) and the Foundation of the University of Southern Indiana.

Literature Cited

1. Clay, W.M. 1975. The Fishes of Kentucky. Kentucky Dept. of Fish and Wildlife Resources, Frankfort, Kentucky. 416 pp.
2. Geo-Marine, Inc. 1985. Ohio River Ecological Research Program — Adult and Juvenile Fish and Ichthyoplankton Studies. Plano, Texas. 418 pp.

3. Gerking, S.D. 1945. The distribution of the fishes of Indiana. Investigations of Indiana Lakes and Streams, 3(1):1-137.
4. Hair, J.D. 1980. Measurement of Ecological Diversity (Chap. 16) in Wildlife Management Techniques Manual (4th ed.), edited by Sanford D. Schemnitz. The Wildlife Society, Inc., Washington, D.C. 269-275 pp.
5. Hoggatt, R.E. 1975. Drainage Areas of Indiana Streams. U.S. Dept. of the Interior, Geol. Surv. Water Resources Division. 231 pp.
6. Hubbs, C.L. and K.F. Lagler. 1942. Annotated list of fishes of Foots Pond, Gibson County, Indiana. Investigations of Indiana Lakes and Streams, 2(4):73-82.
7. Kirtland, J.P. 1854B. *Alburnus nitidus* (silver minnow). Annals. of Sci., Cleveland, Ohio. 2(2):44-45.
8. Kozel, T.R., G.W. Weddle, K.L. Welborn, J.T. Dailey, D.C. Dailey and M.W. Denner. 1981. A fish faunal survey of Posey County, Indiana. Proc. Ind. Acad. Sci. for 1980. 90:446-453.
9. Lagler, K.F. and W.E. Ricker. 1942. Biological fisheries investigations of Foots Pond, Gibson County, Indiana. Investigations of Indiana Lakes and Streams, 2(3):47-72.
10. Lindsey, A.A., D.V. Schmelz and S.A. Nichols. 1969. Indiana Natural Areas. Survey Dept. of Biological Sciences, Purdue University, Lafayette, Indiana. 594 pp.
11. Nelson, J.S. and S.D. Gerking. 1968. Annotated Key to the Fishes of Indiana. Dept. of Zoology, Indiana University, Bloomington, Indiana. 84 pp.
12. ORSANCO. 1962. Aquatic Life Resources of the Ohio River. Ohio River Valley Sanitation Comm., Cincinnati, Ohio. 218 pp.
13. Pearson, W.D. and L.A. Krumholz. 1984. Distribution and Status of Ohio River Fishes. Oak Ridge National Laboratories, Pub. No. ORNL/Sub/79-7831/1. 401 pp.
14. Pflieger, W.L. 1975. The Fishes of Missouri. Missouri Dept. of Conservation. 343 pp.
15. Poole, R.W. 1974. An Introduction to Quantitative Ecology. McGraw-Hill, New York. 532 pp.
16. Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea and W.B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. Amer. Fisheries Society, Special Pub. #12. 174 pp.
17. Smith, P.W. 1979. The Fishes of Illinois. University of Illinois Press, Urbana, Illinois. 314 pp.
18. Trautman, M.B. 1981. The Fishes of Ohio. Ohio State University Press, Columbus, Ohio. 782 pp.
19. Wayne, W.S. 1956. Thickness of drift and bedrock physiography of Indiana north of the Wisconsin glacial boundary. Ind. Dept. Conserv. Geol. Surv. Rept. of Progress, No. 7. 70 pp.

Instructions for Contributors

Eligibility

Indiana Academy of Science members in good standing are eligible to submit papers for publication in the *Proceedings*. When a paper is signed by more than one author, at least one must be a member of the Academy. Preferably, eligibility should be established before submitting the paper, as such papers are given priority. In any case, all authors must be certified by the treasurer for payment of dues and/or old reprint bills at the time of the deadline. Invited papers may be considered for publication regardless of the membership status of the author. If authors are unable to attend the fall meetings, papers read by title by the Section Chair also may be considered for publication.

All papers submitted for publication in full will be reviewed by qualified reviewers (Editorial Board) selected by the Publications Committee. The acceptance of papers for the *Proceedings* is the responsibility of the Publications Committee. Among papers of primarily regional interest, e.g., certain aspects of botany, zoology, geology, geography, and anthropology, those dealing with Indiana material will be accorded preference.

Abstracts

Three copies of an abstract should be submitted to the Section Chair at the time the title of the paper is submitted for the fall program. All abstracts are acceptable for publication in the *Proceedings* if the paper has been presented at the fall meeting. Two copies of the abstract should be marked "for the editor." The third copy of the abstract should be marked "for the section chair." It may include information about time, projection facilities needed, etc. The abstract must be prepared on the "Standard Abstract Form" available from either the Section Chair or the Academy secretary. The abstract should be complete, clear in itself and fit within the borders of the prescribed form.

Deadline at the Editorial Office

Whether sent by the Section Chair as prescribed, or directly to the Editorial Office, all material to be considered for publication in the *Proceedings* must reach the editor by December 1st. This deadline is necessary to comply with the State deadlines for contracts to insure that the publication process remains on schedule.

Preparation of Manuscripts

A. Refer to the latest copy of the *Proceedings* for the accepted style of abstracts and papers, and follow this, especially in literature citations, headings, footnotes, table and figure construction.

B. Type on 11 × 8½-inch bond paper with a new ribbon, leaving some margin. Double space everything, including title, author's name, department and institution, footnotes, quotations, legends and literature list. Manuscripts must be submitted in triplicate. The original will become the printer's copy; if it must be retyped, it will be sent back to the author. Computer prints must be letter quality.

C. Footnotes are to be kept to a minimum. Necessary footnotes are numbered consecutively throughout, and referred to in the text as superscripts, without parentheses.

D. Literature citations are listed alphabetically at the end of the paper, headed Literature Cited. List complete literature citations, i.e., author, date, title, journal, (or publisher, and city) volume and total pages. The highly abbreviated form used in some journals has not been adopted for the *Proceedings*. Follow these models:

    7. Doe, J.B., and R.C. Rose. 1949. New light from old radioactive carbon. J. Amer. Biol. Soc. 34:278-305.
    8. Milazzo, G. 1963. Electrochemistry. Elsevier Publ. Co., New York, N.Y. 708 p. References cited should be numbered consecutively (in the alphabetized list) and should be referred to in the text by number in parentheses on the line of type and before the period if at the end of a sentence.

E. Do not underline anything except scientific names, words to be italicized, and titles of books when they appear in the text only, not in literature list.

F. All literature listed, tables and illustrations, must be referred to in the text.

G. Tables, which are costly to print, should be reduced to a minimum. Avoid small tables, scattered through the text. Each table (including heading) shall be typed on a separate letter-sized sheet and placed at the end of the paper. Outsize tables cannot be accepted.

H. Photographs should be printed on glossy paper and have good contrast. It is best to mount them trimmed to fit tightly together at the edges in groups, on stiff cardboard with rubber cement. Proportion the group for a full page of the *Pro-*

ceedings, or use the full width of the paper (4 1/8″) and any part of the page's height. Do not mix line drawings and photographs in the same group. All figure captions should be on a single letter-size sheet, numbered to correspond and placed at end of paper.

I. The original for line drawings need be no more than twice the size desired for the printed figure. They should be proportioned and arranged to fit the page size of the *Proceedings*. All line drawings must be drawn in India ink, lettered with a lettering set, and of suitable size to allow for necessary reduction. Do not submit printed maps when the necessary reduction will efface the narrower lines or render some of the lettering hardly legible; such maps should be redrawn and lettered in adequate size letters, omitting unnecessary details. All illustrations requiring a size scale must portray the scale in a manner that permits size reduction. Illustrations must be kept to a minimum.

J. Exceptional questions may be answered by checking either the American Chemical Society *Handbook for Authors* or the Council of Biology Editors, Inc., *CBE Style Manual*, 5th edition.

K. Major professors are urged to review all papers by their graduate students, for both form and content, before they are sent in for publication. Of those based on university theses, manuscripts carrying the approval by the professor will be given preference over those without such approval. New authors, especially, are reminded that a scientific paper should summarize the work, not recapitulate it. It must be much more concise than a university thesis, avoiding all extraneous material especially long tables and lists of little interest except to the author. All manuscripts should be as concisely written as possible.

L. Reprints of papers are paid for by authors, at cost. Directions for ordering reprints accompany the galley proof and the orders are placed at the time the author returns the corrected galley proof to the editor. The order forms supplied with the galley proof must be completed and returned to the editor along with any special institutional forms regarding payment for the reprints. Abstracts and notes are not reprinted.

M. The editor needs at the time he mails out galley, current addresses for all authors and co-authors of all abstracts and papers. Many former graduate students lose the opportunity to order reprints when their forwarding addresses are faulty. It is suggested that the student's permanent home address be written on the reverse side of the abstract copy marked "for the editor."

Revised July 1986.

INDEX

Abrell, D. Brian, 200, 401, 421
Abundance and Characteristics of Northern Indiana Wetlands, 249
Acid Sulfate Soils of the Mangrove Swamps of Rivers State, Nigeria, 483
A Comparative Study of the Hamster Kidney Cell Line BHK-21 (C-13) and Normal Hamster Kidney Tissues*, 129
A Comparison of Site Frequencies and Natural Settings in the Tennyson and Shoals Survey Areas in Southwestern Indiana*, 72
A Comparison of Surface Vegetation on Unreclaimed 1949 Indiana Coal Spoilbanks in 1964 and 1981, 257
A Compilation of Plant Diseases and Disorders in Indiana - 1986, 115
A Computer Raindrop Model Used to Predict the Equilibrium of pH of Rainfall over Indianapolis*, 306
Addresses and Contributed Papers, 57
Adhesion and Expansion of Epithelial Cell Sheets*, 130
A Floristic Survey of a Limestone Glade in Versailles State Park, Ripley County, Indiana, 407
A Floristic Survey of the Yellow Birch Ravine Nature Preserve, Crawford County, Indiana, 435
Agee, David M., 507, 523
Aggression versus Courtship in Sticklebacks: The Role of Habituation*, 202
Air Quality Monitoring in Southwest Indiana During the 1986 Growing Season*, 307
Albrecht, Mark, 129
Aldrich, James R., 401
Alvager, Torsten, 135, 385
Alvey, William J., 507
An Ab Initio Aromatic Molecular Calculation on Aromatic-tetracyanoethylene Charge Transfer Complexes, 189
An Estimate of Indiana's Coal Reserves that Comply with Current Sulfur Dioxide Emission Standards*, 316
Analysis of Playback-record Responses in the Male Cricket Frog, *Acris crepitans**, 202
Anez, Angel, 385
An Investigation of the April 1986 Chernobyl Radioactivity Releases as Detected in Muncie, Indiana, 397
Annual Financial Report, 33
Annual Report, Youth Activities, 38
A Note on Dangers in Hypnosis*, 447
Anslinger, C. Michael, 71
Anthropology, 71
A "Partial Cremation" from the Angel Site, Vanderburgh County, Indiana, 91
A Pigmented Northern Blindfish, *Amblyopsis spelaea*, and Notes on Pigmentation in Amblyopsid Cavefishes*, 503
A Polar Area Index Methodology for Forecasting Hemispheric Surface Temperature Trends, 489
Applications of Chromotography/Secondary Ion Mass Spectrometry*, 159
Aquatic Invertebrates and Phytoplankton of Miller Woods Ponds, Indiana Dunes National Lakeshore*, 200
Aquatic Plant Distribution and Mapping of Selected Ponds of Miller Woods, Indiana Dunes National Lakeshore*, 96
Archaeological Excavations at the Lattas Creek Site (12-Gr-29), Greene County, Indiana*, 71
Archaeological Investigation of the DeWeese-Preston House*, 73
Archaeological Research in the Coal Mining Area of Southwestern Indiana*, 72
Arnold, M. Brian, 160
A Search for a Flashier Crown: Synthesis of a Crown Ether with Potassium Ion Enhanced Fluorescence*, 162
Aspects of the Biology of *Carex woodii* Dew. (Cyperaceae)*, 202
A Study of Adenosine Deaminase and Its Conversion Factor in Normal and Pathological Human Serum*, 162
A Study of Adenosine Deaminase in the Fruit Fly, *Drosophila melanogaster**, 503
A Study of the Coordination Compounds of Some Transition Metals with 2-amino-2-methyl-1,3-propanediol, 197

Atomic Spectroscopic and Neutron Activation Analyses of Trace Heavy Metals in Water Supplies Surrounding a Municipal Landfill*, 160
Avian Surveys along Two River Segments in Southern Indiana, 223

Background Levels of Potential Toxicants in Indiana Stream and Lake Sediments*, 305
BACKS, STEVE E., 223
BACONE, JOHN A., 205
BAILEY, SHEILA M., 367
BAIN, JOHN, 159
BAKER, CLAUDE D., 459, 503
BARD, M., 367
BARR, RITA, 139
BARTON, JAMES D., 209
BARTON, SCOTT J., 201
Bathocuproine Disulfonate and Interferon: Progress and Prospects*, 368
BAUBE, CHARLES L., 199
BAYER, SHIRLEY A., 129
BEACH, DAVID, 385
BECK, SIDNEY L., 506
BEHFOROUZ, MOHAMMAD, 159, 161
BEHFOROUZ, NANCY C., 367
BELCHER, DANIEL, 97
BENNETT, ALICE S., 131
BENNETT, DIANA S., 387
BERGER, KENNETH D., 507, 523
BERNDTSON, AMY K., 503
BERRY, JAMES W., 199
BHATTACHARYA, PRADEEP K., 95
Bimodal Size Distributions of Even-aged Populations: Their Origins and Effects on Community Structure in Larval Salamanders*, 199
BINKOWSKI, F.P., 505
BLACK, BRUCE A., 287
BLACK, KATHRYN N., 449
BOCK, PAUL L., 160, 161
BONEHAM, ROGER F., 317
BONHOMME, HAROLD, 306, 309
Botany, 95
BRAND, DAVID L., 503
BRANKA, CAROL, 369
BRIDGES, C. LEE, 309
BRIGHT, GREG R., 305, 306, 309
BRINKER, RUTH A., 71
BUCHKOWSKI, MATTHEW, J., 387
BUCKLAND, DONALD E., 243
BURKE, ANGELA M., 129
BURKETT, FRANK N., 75
BURNETT, A.S., 367
BURROWS, L.S., 367
BUSCH, KENNETH L., 159
BYE, CHERYL A., 160, 387, 397

Calmodulin Antagonists Inhibit Oral Regeneration in the Ciliate *Stentor coeruleus**, 132
CALVERT, JAY G., 368
CAMPAIGNE, ERNEST E., 57, 165, 173
CANTIN, MARK E., 71
CARTER, BRADLEY H., 306
CASEBERE, LEE A., 401
CASTRALE, JOHN S., 215, 223
Cell and Tissue Development in One and Two Year Old Culms of *Arundo* donax L., 113
Cell Biology, 129
Ceramics and Cermaic Sites in the Upper Wabash Drainage: A Regional Problem, 72
CERVONE, THOMAS H., 506, 507, 523, 553
Changes in Host-nuclear Macromolecules in Resistant and Susceptible Barley to Infection by *Erysiphe graminis* f. sp. *hordei* Culture CR3*, 95
Changing Attitudes toward Homosexuality*, 447
Characterization of SPR6, a Sporulation Regulated Gene in Yeast*, 369
Chemistry, 159
Chemistry at Indiana Asbury-DePauw in the Nineteenth Century*, 351
CHERNOFF, E.A.G., 130
CHESAK, DAVID D., 287
CHESAK, DONALD T., 287
CHRISTENSON, CARL, 459
CHRISTENSON, JACQUELINE, 459
CLANCY, MARY J., 369
CLARK, D.E., 309
COCHRAN, DONALD R., 72
COLE, THOMAS A., 130
Comparative Effects of Abscisic Acid and Indole Acetic Acid on Phospholipid Bilayers*, 97
Comparison of Groundlayer and

Shrublayer Communities in Full Canopy and Light Gap Areas of Hoot Woods, Owen County, Indiana, 421
Con A Binding Sites in the Ciliate *Stentor coeruleus* Are Located in the Membranellar and Somatic Cilia*, 131
CONNER, GARRE A., 321
Construction of Highway Embankments over Amorphous Peats and Mucks*, 481
COOK, DONALD J., 351
Corporate Members of the Academy, 50
CORTWRIGHT, SPENCER A., 199
COSTELLO, PRISCILLA, 504
Coteratogenesis of Caffeine and Acetazolamide in Mice*, 506
CRANE, FREDERICK L., 139, 377
Creation of an Urban Acid Deposition Database*, 306
CROWL, TIMOTHY, 481
Cryptograms Collected by Thomas G. Lea from Indiana and Ohio, 1836-1842, 403
CUDMORE, WYNN W., 543
CURRAN, TIMOTHY T., 161

DAILY, FAY KENOYER, 403
DANIEL, JEANNETTE L., 131
DANIELL, DAVID L., 504
Darwinism in Modern China, 473
DAVIS, FLOYD A., 145
DAVIS, GRAYSON S., 504
Decreased Survival of *Leishmania tropica* in Macrophages Treated with Cyclosporine A*, 367
Degradation of Liver HMGCoA Reductase in Vitro*, 130
Development of the Neostriatum in the Rat Brain*, 129
DHAWALE, S.W., 160
Diabetes-induced Decrease in Sodium Pump Activity in Rat Soleus Muscle*, 132
Dietary Effects of Tannic Acid on the Gut Microflora of Sprague-Dawley Rats*, 369
Differential Sensitivity of Muskmelon and Watermelon Cultivars to Ozone-induced Foliar Injury, 121
Disturbance Effects in Oak Dominated Forests of Central Indiana*, 203
DODSEN, PATRICIA, 461
DOLPH, GARY E., 99
DOSS, PAUL K., 333
DUFF, SUSAN, 531
DUNBAR, KERRY B., 97
DUWELIUS, RICHARD F., 315

Early Root Development of Planted Red Oak Seedlings in Clearcut Forest Openings*, 200
EBERLY, KARA, 369
Ecology, 199
Effect of Caffeine on Contractility of Frog Skeletal Muscle*, 132
Effects of Extracellular Sodium and Calcium on Acetylcholine Induced Hyperpolarizations in Mouse Parotid Cells*, 131
Effects of Fire on Invasion and Community Structure of a Southern Indiana Cedar Barrens, 273
Effects of Prescribed Burning on Woody and Herbaceous Vegetation in Black Oak Sand Savannas at Hoosier Prairie Nature Preserve, Lake County, Indiana, 205
Effects of Retinoids on Phospholipid Bilayers*, 129
Efficiency and Pattern of ^{65}Zn Incorporation into Soybean Seeds by Root Absorption, Stem Injection, and Foliar Application*, 96
EGAR, MARGARET W., 505
Electron Impact Mass Spectrometry of β-Alkylhydrocinnamate Methyl Esters*, 161
Electron Spin Resonance of Membranes*, 161
Energy Expenditure and Maximum Life Span, 135
Engineering, 287
Engineering Aspects of Heavy Duty, On and Off Highway, Trailers*, 287
Enhancement of Phenol Biodegradation by Soil Inoculation*, 305
Entomology, 289
Environmental Quality, 305
Evolution of Reproductive Isolation in Two Species of Toad*, 200

Examination of a Popular Belief: Is There a Relationship between Winter and Summer Temperatures?*, 316
Experiential Training: Evaluation and Grading of Extended Field Trip Courses*, 459

Farazi, Vida, 159, 160
Farlee, L.D., 200
Farrar, Donald R., 429
Fast-neutron-Activation Analysis of Various Water Sources of East Central Indiana, 387
Fault Tolerant Computing*, 287
Faust, Frederick, 368
Fernandus Payne, Educator and Scientist, 361
Fiber Optic System for Sensor Applications and Environmental Control*, 385
First Activities of the Physics Kind: Physical Science Activities for the Primary Grades, 461
Fischer, B.C., 200, 231
Fishes of Goose Pond and Its Drainage Basin, 553
Food and Ectoparasites of Shrews of South Central Indiana with Emphasis on *Sorex fumeus* and *Sorex hoyi*, 543
Foos, K. Michael, 95
Franzmeier, D.P., 497
Freeland, Leah J., 447
Friedle, Dennis A., 369
Friends with Fins: Using Fish as an Educational Tool*, 459
Functionalized Crown Ethers: Benzo Crowns with P(III) Centers*, 159

Gaddis, W.S., 315
Galbraith, Michael T., 553
Ganion, Larry R., 504
Ganion, Susan J., 160
Gap Structure in a Mature Till Plain Forest*, 204
Garcia, Robert, 368
Geib, Roy W., 447
Geology and Geography, 315
George, C.A., 231
George, D.W., 231
Gibson, David M., 130
Ginn Woods: An Undisturbed Virgin Forest in East-central Indiana*, 201
Gochee, Angel V., 200
Goebel, Edwin M., 368, 369
Goetz, Frederick W., 503, 505
Goodson, Ted III, 130
Grant, Richard H., 307, 481
Gray, Henry H., 345
Green, R.J. Jr., 95
Grimes, Roy, 243
Groth, James V., 402
Ground-water Modeling of Small Watersheds in the Coal-mining Region of Southwestern Indiana*, 315
Grove, Stanley, N., 369
Grow, David E., 333
Gubitosi, A., 131
Gustin, William A., 316

Habitat and Food Interrelationships of Shrews in West Central Vigo County*, 505
Hall, Robert D., 333
Hankins, Marie, 181
Hardy, Kathleen, 369
Harley, Shawn B., 459
Hartmann, Walter, 447
Hasenmueller, Walter A., 316
Heiser, Charles, 401
Helms, Ronald L., 505
Hicks, Ronald, 75
Hilgeman, Sherri L., 83
Hippensteel, Peter A., 305
Histochemical Observations of Embryogenesis in Suspension Cultures of *Asclepias tuberosa* (Asclepiadaceae)*, 97
Histopathology of Experimental *Dendritobilharzia pulverulenta* Infections in Avian Hosts*, 504
History of Science, 351
Hogarth, A.J.C.L., 467
Holland, Russell, 305
Homoya, Michael A., 407, 429
Hoosier Science and Engineering Fair, 41
Horn, Mark A., 159
Host Range and Geographic Distribution of *Chionaspis heterophyllae* Cooley and *C. pinifoliae* (Fitch) (Homoptera: Diaspididae), 297
Howell, David, 223, 243
Howes, Ruth H., 61, 461
Hults, Malcom E., 385

HUSS, MARY E., 161

IANNACONE, RICHARD F., 369
Identification of Members of Species-groups of Genus *Paramecium* with Fluorescent, DNA-binding Dyes*, 130
Impact of Heavy Metal Pollution on Sediment Bacteria in the Maumee River*, 306
Improved Analysis of Physical Forces and Tissue Rheology in Amphibian Gastrulation*, 504
Incidence and Control of Cucurbit Powdery Mildew in Indiana*, 96
Index, 563
Indiana Science Talent Search, 28
Indiana's Property Tax Incentive Program for Wildlife Habitat Protection, 243
Influence of Dietary Fatty Acids on Murine Mammary Cell Types*, 131
INMAN, VIRGIL W., 537
Insects and Other Arthropods of Economic Importance in Indiana in 1986, 291
Insects in Traditional Chinese Medicine*, 289
Instructions for Contributors, 559
Interaction of Some Metals and Tetrathionate Ions*, 160
ISIRIMAH, N.O., 483
Isolation and Identification of *Azospirillum* and *Herbaspirillum* Strains from Soil of Several Eastern States*, 368
Isolation of Mevinolin Resistant Strains in Yeast*, 367

JACKSON, MARION T., 200, 401, 421
JARIAL, MOHINDER S., 505
JARRETT, HARRY W., 368, 370
JENSEN, RICHARD J., 402
JOCKEL, JENNY I., 368
JOHNSON, ERIC R., 163
JOHNSON, JIMMY J., 316
JOHNSON, WILLIS H., 130

KABLE, JULIE A., 449
KAPLAN, JEROME I., 161
KENDRICK, JAMES W., 72
KERSHAW, J.A., JR., 231
KESLER, THOMAS E., 317
KHAN, ALAM, 96
Kindling Rates in Sprague Dawley Rats as a Function of Copper and Nichrome Electrodes, 453
KING, KARL K., 459
KING, THOMAS, 135
KIRSCH, JOSEPH L., 185, 189
KJONAAS, RICHARD A., 161
KLINE, RICHARD M., 371
KOSKA, JANE F., 200
KRAMER, ROSALIE J., 459
KRAMER, STEPHANIE A., 531
KRITSKY, GENE, 289, 473
KRUGER, TERRY L., 161, 163

LAFUZE, JOAN E., 133
LANE, N. GARY, 353
Later Immune Reactivity as a Function of Experience before Weaning and Strain of Mouse: A Preliminary Investigation*, 447
LATIN, RICHARD X., 96, 115
LAUER, T.E., 309
LEATHERLAND, SCOTT A., 506
Leatherleaf Bogs of Indiana*, 401
LEE, MICHAEL I., 131
LEECH, CURTIS K., 453
LEINENBACH, BRAD J., 507
LENN, SUSAN E., 553
LIAN, ELIZA HUI CHIEN, 453
Localization of Acetylcholine Binding Sites in Prepubertal Mouse Ovaries*, 504
Location of Sites on Calmodulin that React with a Phenothiazine*, 368
LOEWENSTEIN, DAVID L., 387
LORSCH, P.D., 505
LOVELL, C.W., 481
LUCCHESE, LEONARD, 185
Lyme Disease in Indiana: Isolation of *Borrelia burgdorferi* from Ticks (*Dermacentor variabilis* and *Amblyomma americanum*) and White-footed Mice*, 370

McCAIN, JOHN W., 402
McCLAIN, MARK S., 201
McCOLLUM, DAVID L., 161
McCOMISH, THOMAS S., 201
McFEE, B., 307
McFEE, WILLIAM W., 481
McINTYRE, JAMES R., 489

Ma, Pang Fai, 129, 162, 503
Mabry, Thomas E., 162
Magnetic Resonance Investigation of Metal Complexes of Antidiabetic Drugs*, 163
Maloney, Michael S., 131, 132
Manalis, Richard S., 132
Martin, Owen Jr., 139
Massom, Larry R., 370
Matchuny, James K., 368
Maxam, Thomas E., 96
Maxwell, Richard H., 413
Mechanisms of Reproductive Isolation in Two Sympatric Stickleback Species*, 199
Menges, Eric S., 273
Meyer, Robert W., 291
Michael Addition and Derivatives of 2-Carboxamido-3-phenylindenone, 165
Microbiology and Molecular Biology, 367
Microcosm Acid Rain Experiments with Water from Oriole Pond, Perry County, Indiana*, 201
Milano, Carmelo A., 369
Miller, Louis V., 316
Miller, Steven J., 130
Mills, W.L., 231
Minutes of the Budget Committee Meeting, 29
Minutes of the Fall Meeting (Council), 18
Minutes of the Fall Meeting (Executive Committee), 17
Minutes of the Fall Meeting (General Meeting), 24
Minutes of the Spring Meeting (Council), 12
Minutes of the Spring Meeting (Executive Committee), 11
Modification of Pyridine Nucleotide Pools in Hela Cells Grown under Growth Promoting Factors, 377
Mohr, Mary E., 504
Moldenhauer, W.C., 497
More on: Do Tadpoles Die for Their Siblings?*, 201
Moriarty, Robert M., 163
Morré, D.J., 377
Morse, Mary Ann, 477
Mueller, Bruce, 287
Muir, Patricia S., 306
Munford, John W., 132
Munsee, Jack R., 257

Natural Area Remnants within the Indiana Army Ammunition Plant, Charlestown, Indiana: The Little Bluestem Glades, 413
Nature Study: A Practical Science Course for the Non-science Major, 477
Navas, P., 377
Necrology, Fay Kenoyer Daily, Necrologist, 44
Nelson, Craig E., 201
Neuropteris Ovata in Lacustrine Facies Sequence below Raben Branch Member (Patoka Fm.) at St. Wendel, Indiana and Related Carboniferous Reconnoissance Investigations*, 321
Neurotransmitter Release Simulation*, 132
New Artificial Hybrids in *Helianthus**, 401
New, Jimmy F., 249
Newman, James E., 489
New Members for 1986, 51
New Reef Structures in Daviess County, Indiana, 317
Nichols, David S., 553
Nisbet, Jerry J., 113
Notes on the Life History of the Intertidal Spider *Paratheuma insulana* (Araneae; Desidae)*, 199
Nussbaum, Elmer N., 385

Ober, David R., 387, 397
Observing Halley's Comet from Indiana and Brazil*, 385
Officers and Committees for 1986, 3
Ojanuga, A.G., 483
Optimum Growth Temperature for *Pilobolus**, 95
Ossom, E.M., 483

Pace, Robert E., 72, 73
Page, Lester A., Jr., 197
Parke, Neil, 306
Parker, George R., 203, 204
Parker, R.A., 367
Parkhurst, David F., 201

PC-SIG: A Communications Systems Laboratory*, 287
PECKNOLD, PAUL C., 115
PERRILL, STEPHEN A., 202
Pesticide Use in No-till Row-crop Fields Relative to Wildlife, 215
PETERLIN, ALBERT, 489
PEZESHK, ABBAS, 163
Physics and Astronomy, 385
PICKELHEIMER, BRUCE, 132
PINGER, ROBERT, 370
Plant Taxonomy, 401
PLAYL, LAUREN A., 370
Pollination, Nutrient and Energy-limited Female Reproductive Success in *Catasetum ochraceum* Lindl. (Orchidaceae)*, 202
POPE, SUZY, 163
POST, THOMAS W., 205
Potassium Ion Induced Enhancement of Crown Fluorescence by Displacement of a Complexed Quencher*, 160
Preliminary Polyacrylamide Gel Electrophoresis (PAGE) Survey of Isozymes in Populations of the Bean Rust Fungus*, 402
Preliminary Report of Test Excavation of Swan's Landing Site (12HR 304), Harrison County, Indiana, 1986*, 71
Presidential Address, 57
PRIBUSH, ROBERT A., 306
Progress in the Treatment of Cultural Resources in the Coal Fields of Indiana*, 71
Progress toward a Photographic Field Guide to Indiana Wildflowers*, 402
Project Map: An Evaluation of a Community*, 459
Proteolytic Enzymes in Brook Trout and Goldfish Follicles during Final Maturation and Ovulation*, 503

Psychology, 447

Quo Vadis or If Nobody Does Anything, Nothing Will Be Done, 57

Radon Daughter Concentrations in Selected Homes in Indiana, Illinois and Michigan*, 385
Ray, J.K., 309
Reactions of Lithium Triorganozincates with Acid Halides*, 161
Reactions of Phenyl (β -N-benzenesulfonyl indolyl) Iodonium Chloride with Soft Anions*, 163
REDMOND, BRIAN G., 72
Redox-induced Proton Excretion by Cultured Carrot Cells Is Affected by Protonophores and Inhibitors of ATPase, 139
REINERT, D., 307
Results of Surface Water Investigations of the Grand Calumet River/Indiana Harbor Canal Basin*, 306
RHYKERD, C.L., 483
RICHARDS, RONALD L., 513
RIEMENSCHNEIDER, VICTOR, 537
RITTER, MARTHA M., 370
ROBBINS, LEONARD H., 203
ROBERSON, DANNY LEE, 132
ROE, CATHERINE M., 449
ROLLEY, ROBERT E., 249
ROMERO, GUSTAVO A., 202
ROSS, DEBORAH D., 305, 306
ROTH, JON A., 385
ROTH, ROGER W., 385
ROTHROCK, PAUL E., 202
ROWLAND, W.J., 202
ROYER, JUDITH A., 95
RUCKMAN, PEGGY L., 96
RUD, JEROME, 306, 309
RUHL, GAIL E., 115
RYBARCZYK, JAMES P., 160, 162

S-Adenosylmethionine Synthetase and Spore Germination in *Mucor racemosus**, 368
SANQUENETTI, DOUGLAS, 161
SCHAUF, CHARLES L., 145
SCHEERINGA, KEN L., 489
SCHMALZ, CHRISTOPHER A., 371
SCHMELZ, DAMIAN V., 209
SCHNITZER, SAMUEL B., 447
SCHROCK, JOHN RICHARD, 257
SCHUDER, DONALD L., 297
SCHULTHESIS, SUSAN J., 523, 553
SCHURR, MARK R., 83, 91
Science and National Security, 61
Science Education, 459

Scott, Donald H., 115
Scott, Roger L., 385
Sehra, Ruchir, 130
Self-ratings of Masculinity and Femininity by High School Students, 449
Separation and Characterization of Chitinase and Chitobiase from CDC Group *EF4a**, 367
Serum Angiotensin Converting Enzyme Changes in Rabbits Following Neutrophil Activation *in vivo**, 133
Sever, David M., 531
Shaffer, N.R., 315
Sharkitt, John, 162
Shepherd, William, J., 202
Sherman, Louis A., 370
Sherwood, Paul T., 203
Shour, Mark H., 297
Siefker, Joseph R., 197
Significant Clovis Sites in Southwestern Indiana*, 72
Simini, Michael, 121, 307
Simon, Edward H., 368
Simon, James E., 121, 307
Site Distribution and Physiographic Zones along the Big Blue River Glacial Sluiceway, 75
Smith, David R., 459
Smith, Scott A., 131
Snow, John T., 459
Snyder, David L., 537
Snyder, Richard G., 121
Soil and Atmospheric Sciences, 481
Solution Calorimetry Studies of Hydrogen Bonding in Aliphatic Alcohols, 185
Sousa, Lynn R., 160, 162
"Speaker of the Year" Address, 1986-87, 61
Spectroscopic Studies of Spin-labeled Tetracycline Metal Complexes*, 163
Spotting Spurious Stream Names on Topographic Maps of Indiana, 345
Squiers, Edwin R., 203
Stahl, James, 306
Stark, R.J., 131
Starkey, Jeffrey T., 162
Steinhardt, G.C., 497
Stephens, Kay, 163
Stephenson, Gregory A., 162
Sterilization of Chinook Salmon, *O. tshawytascha*, Fry by 17α-methyltestosterone*, 505
Stevenson, Michael J., 306, 447
Stillwell, William, 97, 129, 161
Storhoff, Bruce N., 159, 160
Strait, Rebecca A., 421
Stream-variable Response to a Change in Surficial Geology: Middle Fork, Big Walnut Creek, Hendricks County, Indiana, 333
Strouse, Kimberly K., 163
Studies of Ecology, Ectoparasites, and Other Associates of the Eastern Box Turtle, *Terrapene carolina**, 503
Studies Toward the Total Synthesis of Lavendamycin Methyl Ester, an Antitumor Antibiotic Agent*, 159
Substituted Derivatives of 3a,4,5, 6-Tetrahydrosuccinimido[3, 4-b]acenaphthen-10-one.II, 173
Sulfur Isotope Ratios in Indiana Sulfide Minerals*, 315
Summer Fishes of Pigeon Creek Drainage, 523
Summer Primary Productivity and Associated Data for Four Indiana Rivers, 309
Sun, I.L., 377
Swinney, Stephen C., 163
Symptomatic Therapy for Demyelinating Diseases: The Role of Basic Science, 145
Synthesis and Characterization of Protein A-silica for High Performance Affinity Chromatography*, 370

Tankersley, Kenneth B., 72
Templer, David, 165, 173
The 1986 IU/GBL Excavations of the Stephan-Steinkamp Site (12Po33), 83
The Assessment of Interactions among Ovipositing Goldenrod Gall Flies, *Eurosta solidaginis*, Fitch*, 203
The Construction of Three Hybrid Cloning Vectors and the Use of Low Iron Medium to Improve Transformation Efficiency in the Cyanobacteria *Anacystis nidulans* R2 and *A. nidulans* R2 SPc., 370
The Effect of *Azospirillum* and *Herbaspirillum* Inoculation upon the

Yield of Winter Wheat (Triticum aestivum)*, 369
The Effects of Bulk Density on Available Moisture in Selected Surface Mine Soil Materials, 497
The Fern Genera *Vittaria* and *Trichomanes* in Indiana, 429
The Mechanism of L-Ascorbic Acid Entrapment in Human Erythrocytes*, 164
The NASA Technology Utilization Program*, 287
The Preparation of Functionalized Aza Crown Ethers*, 160
The Purdue Atmospheric Science Education Program for Junior High Science Teachers*, 459
The Quaternary Distribution of the Eastern Woodrat, *Neotoma floridana*, in Indiana, 513
The Relation between Ovum Variability and Larval Growth in *Ambystome tigrinum* (Amphibia: Urodela), 531
The Relationship between Cl and SO_4 Particulate Concentrations and Air Masses*, 481
The Relationship between Weed Community Development and Tillage Type in Grant County, Indiana*, 203
The Richard Owen Geological Survey of Indiana 1859-1860, 353
The Upland Sandpiper, *Bartramia longicauda*, Breeding Area in South Bend, Indiana, 537
The Use of Aniline as an Indicator of Persistence in Environmental Studies, 371
The Use of Pyridine to Quench the Dansylation of Amino Acids*, 163
The Variation of Four Bioclimatic Indexes in Indiana, 99
The Water Quality of Northeastern Indiana Lake Inflows*, 305
The Yankeetown Phase: An Emergent Mississippian Cultural Manifestation in the Lower Ohio River Valley*, 72
Thirty Years of Growth Records in Donaldson's Woods, 209
THOMAS, CINDY, 385
THOMAS, GERALD P., 386
THOMPSON, SUE, 386
Three-dimensional Profiling of Matrix-interferences in the ICP*, 162
TOBOLSKI, JAMES J., 369
TOMACK, CURTIS H., 72
Tree Regeneration Response to Clearcutting on the USFS Brownstown Ranger District, 231
TRUMPEY, JOSEPH E., 132
TUNCAY, ATILLA, 163
Two Decades of Change in the Forest Structure of Virgin Coast Redwoods (*Sequoia sempervirens*) D. Don(Endl.) in Stout Grove, Del Norte County, California*, 200
Two Decades of Change in the Tree Stratum of Hoot Woods, Owen County, Indiana*, 401

ULRICH, JOHN M., 287
Ultrastructural Changes in the Proximal Tubule of the Axolotl*, 505
Ultrastructure of Articulated Laticifers in *Stapelia bella* (Asclepiadacea), 96
URBANO, CHARISSA M., 506

Validation of a Test to Identify Erythro and Threo Diastereomers of RCHDCHDX Compounds: Variable-temperature NMR Studies of 2-Chloroethanol*, 161
VANN, CAROLYN N., 370
Verticillium dahliae as a Biocontrol Agent of Velvetleaf *Abutilon theophrasti**, 95
VESELACK, MARILYN SUE, 113
Voice Recognition and Speech Synthesis as Aids in Real-time, Computer-aided Measurements of High Energy Physics Star Events in Nuclear Emulsion*, 386
VOLKMAN, B.F., 189
VOLTMER, DAVID R., 287

WADE, KIMBERLY A., 273, 306
WAGNER, EUGENE S., 164
WAGNER, HOLLY A., 73
WAITE, MARY E., 73
WALSH, PATRICIA R., 132
WALTON, ROD, 203
WARD, JEFFREY S., 204
WARNES, CARL E., 367

WASSALL, STEPHEN R., 97, 129, 161
WATSON, ELIZABETH, 369
WEAVER, C.M., 96
Weight Titrations: A Forgotten Art?, 467
WENGER, CHARLOTTE, 367
WHITAKER, JOHN O. JR., 543
WHITE, WILLIAM E., 164
WHITESELL, C. DAVID, 162
WHITMAN, RICHARD L., 96, 200
Who's Teaching Chemistry in Indiana High Schools?, 181
WILEY, G.L., 95
WILSON, KATHRYN J., 96, 97
Winter Fishes in Bayou Creek Drainage*, 506
Winter Fishes of Stinking Fork, 507
WINTERS, J.L., 309
Within Tree Leaf Variability and Evidence for a Developmental Difference Between Pin Oak and Black Oak*, 402
WOLSKE, MARTIN B., 453
WONG, WILLIAM W., 397

YATSKIEVYCH, GEORGE, 429, 435
YATSKIEVYCH, KAY MCCRARY, 402, 435
YEAGER, RUSTY K., 523, 553
YEO, S.E., 505
YOUNG, FRANK N., 361

ZARRINMAYEH, HAMIDEH, 159
ZIMMER, STEPHEN P., 133
Zoology, 503